KATRIN: an experiment to determine the neutrino mass from the beta decay of tritium

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KATRIN is a very large scale tritium-beta-decay experiment to determine the mass of the neutrino. It is presently under construction at the Karlsruhe Institute of Technology north campus, and makes use of the Karlsruhe Tritium Laboratory built as a prototype for ITER. The combination of a very large retarding-potential electrostatic-magnetic spectrometer and an intense gaseous molecular tritium source makes possible a sensitivity to neutrino mass of 0.2 eV, about an order of magnitude below present laboratory limits. The measurement is kinematic and independent of whether the neutrino is Dirac or Majorana.

In beta decay the electron and neutrino share the available energy in a statistical fashion, and in a small fraction of the decays the electron will take almost all the energy unless some must be reserved for the rest mass of the neutrino. The phase-space available to the electron near the endpoint is therefore modified by neutrino mass. The average mass of the three eigenstates must lie between 20 meV and 1800 meV, the lower limit arising in the 'normal' hierarchy if the lightest mass is also negligibly small, and the upper limit being set by the Mainz and Troitsk experiments on the beta decay of tritium [1, 2]. Above an electron-flavor-weighted mass of 20 meV the beta spectrum is indistinguishable from what a single massive 'electron neutrino' would produce if mass eigenstates were also flavor eigenstates. Tritium has a low endpoint energy, which makes the modification caused by neutrino mass a larger fraction of the total spectrum:

$$^{3}\mathrm{H} \rightarrow {}^{3}\mathrm{He}^{+} + \mathrm{e}^{-} + \overline{\nu}_{\mathrm{e}} \quad + 18580 \text{ eV}.$$

Atomic or molecular effects are important at the eV level, and T or T_2 are simple enough to permit highly precise calculation.

A neutrino mass in the quasi-degenerate regime that KATRIN is designed to explore would be of cosmological importance, having a major influence on the formation of large-scale structure in the universe. In addition, KATRIN is sensitive to admixtures of putative sterile neutrinos with masses in the range eV to keV, and offers thousand-fold improved sensitivity to the capture of relic neutrinos.

The KArlsruhe TRItium Neutrino experiment [3] consists of seven major subsystems, a gaseous tritium source, the tritium processing and recirculation system, a differential pumping section, a cryogenic Ar frost pumping section, a pre-spectrometer, a main spectrometer, and the detector system. Delays have been experienced owing in part to vendors changing hands during the performance of contracts, but these issues are believed now to be completely resolved, and data-taking is expected to begin in 2015. Funding for the project is being

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References

[1] Kraus C *et al.* 2005 *Eur. Phys. J.* **C40** 447–468 (*Preprint* `hep-ex/0412056`)

[2] Aseev V *et al.* (Troitsk Collaboration) 2011 *Phys.Rev.* **D84** 112003 (*Preprint* `1108.5034`)

[3] Angrik J *et al.* (KATRIN) 2004 FZKA-7090, http://www.katrin.kit.edu/