PROCEEDINGS OF SCIENCE

Status of the KATRIN Experiment

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The Karlsruhe Tritium Neutrino (KATRIN) experiment is the next generation tritium beta decay experiment to perform a direct, model independent measurement of the absolute neutrino mass scale with an unprecedented sensitivity of 0.2 eV/c^2 at 90 % C.L. Presently under construction at the Karlsruhe Institute of Technology in Germany, KATRIN will use a windowless gaseous tritium source, a large magnetic adiabatic collimation-electrostatic filter and a multi-pixel silicon detector to look for a distortion at the endpoint of the beta decay electron spectrum.

This report summarizes recent developments and the current status of the experiment.

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1. Introduction

Various neutrino oscillation experiments have proven, that neutrinos have nonzero masses [1]. While oscillation experiments can only determine the mass splittings, laboratory β decay experiments provide access to the absolute mass scale through basic kinematical observations [2]. Thus no model assumptions about the dirac or majorana nature of the neutrino have to be made. The KArlsruhe TRItium Neutrino (KATRIN) experiment, presently under construction, will perform a shape analysis close to the tritum beta spectrum endpoint, extracting the effective electron antineutrino mass

$$m_{\bar{\nu}_e} = \sqrt{\sum_i |U_{ei}|^2 m^2_{\bar{\nu}_i}}$$

as an incoherent sum over the neutrino mass eigenstates ν_i with U_{ei} being elements of the neutrino mixing matrix. KATRIN is designed to reach an unprecedented neutrino mass sensitivity of 0.2 eV/c^2 at 90 % C.L. after five calendar years of data taking [3].

2. Setup

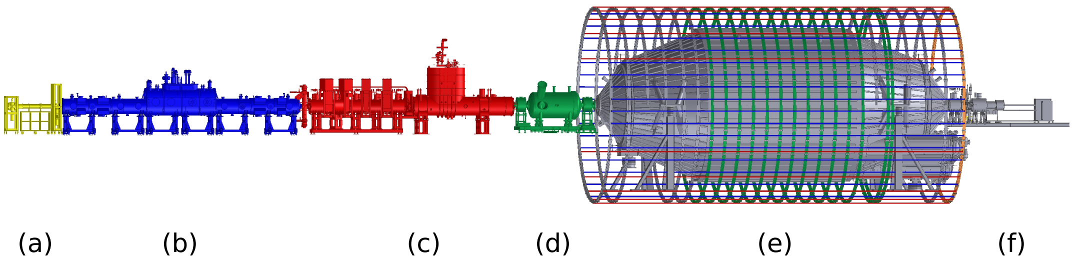

Figure 1: The KATRIN beamline

The KATRIN setup is illustrated in figure 1. It consists of a rear section (a), monitoring the stability of the windowless, gaseous tritium source (WGTS, b). The tritum β decay electrons are adiabatically guided along magnetic field lines through a differential and cryogenic pumping section (c) towards the two spectrometers. The pre spectrometer (d) filters the low energy part of the β spectrum. The main spectrometer with a length of 23.8 m and a diameter of 9.8 m (e) analyizes the electrons' energy with a high resolution of 0.93 eV. Both spectrometers operate on the principle of MAC-E filters (Magnetic Adiabatic Collimation with an Electrostatic Filter) [4]. The resolution of these energy high-pass filters is given by the ratio of the minimum magnetic field reached at the electrostatic barrier in the analyzing plane, located in the middle of the spectrometer, and the maximum magnetic field between the source and the spectrometer. A segmented silicon PIN diode detector (f) acts as an electron counting device [5].

3. Key Requirements for as Successful Mass Determination

The WGTS is designed as a high luminosity source, providing $O(10^{11})$ electrons per seconds. The tritium gas has to be maintained at a temperature of $T = 30\,\mathrm{K}$ with $\Delta T = 30\,\mathrm{mK}$ [6]. The sensitivity of the MAC-E filter spectrometers depends on a well defined magnetic field configuration and a sharp electrostatic retarding potential, which requires a voltage stability at the ppm level. An ultra high vacuum within the main spectrometer of $O(10^{-11})$ mbar ensures that no significant fraction of the beta electrons is scattered off residual gas [7]. Any background originating from cosmic radiation or radioactive decays has to be kept at an extremely low level below 10 mHz [8].

4. Recent Commissioning Milestones

The low field air coil system, allowing for fine shaping of the magnetic field in the spectrometer section and compensation of the earth magnetic field [9] has been installed in mid 2011.
A two-layer wire electrode consisting of 23,440 wires, which covers the inside of the main spectrometer vessel, has been sucessfully installed in mid 2012. Theses wires will be held at a slightly negative potential, thus preventing secondary electrons produced by cosmic radiation, to enter the flux tube [10].
The main spectrometer has been baked out to a temperature of 300 °C in March 2013.
In May 2013 the detector section and main spectrometer were connected and an angular resolved egun [11] was installed on the source side of the spectrometer to start an initial commissioning phase. These measurements verified system functionality, while performing successful tests on the spectrometer resolution, detailed background studies, as well as hardware and software optimization.

5. Outlook

A second commissioning phase of the spectrometer and detector section will follow in mid 2014. The transport section is under construction and expected to be delivered in spring 2014, the source section is expected to follow in mid 2015. KATRIN is anticipated to start data-taking in early 2016. Within five calendar years from then on, KATRIN will perform a model independent measurement of the absolute neutrino mass scale, outmatching previous tritium beta decay in sensitivity by at least an order of magnitude.

6. Acknowledgments

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