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Simulation and measurement of the suppression of radon induced background in the KATRIN experiment

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The objective of the Karlsruhe Tritium Neutrino experiment (KATRIN) at the Karlsruhe Institute of Technology (KIT) is the measurement of the effective electron neutrino mass with a sensitivity of 200 meV/c^2. A central component is the Main Spectrometer (MS), a MAC-E filter type electrostatic high pass filter for electrons. It measures the energy of β-electrons from tritium decay close to the endpoint at 18.6 keV with high precision at a low count rate of 10^{-2} cps in the last eV of the spectrum. The target value for the background rate in the KATRIN design is 10^{-2} cps. The large ultra-high-vacuum chamber of the MS has a volume of 1240 m^3 and is operated at an ultra-low pressure in the range of 10^{-11} mbar, which is required to reduce the background rate. The pumping system of the MS consists of turbo-molecular pumps and large-scale getter pumps (SAES St707 non-evaporable getter (NEG) strips). The NEG strips (^{219}Rn, $t_{1/2} = 3.9$ s), as well as the stainless steel walls (^{220}Rn, $t_{1/2} = 56$ s) are known to emanate small amounts of radon atoms, increasing the intrinsic background rate by 0.5 cps, if no further countermeasures are taken.

Therefore, three LN2-cooled cryogenic baffles (1.7-m diameter), made of L-shaped copper panels, have been installed in front of the NEG-pumps, reducing the transmission of radon into the main volume. Radon from the walls and welds of the vacuum chamber, which is directly emanated into the main volume, has to be removed quickly enough before it decays. However, radon does not stick to a cold surface indefinitely. It either desorbs after a limited sojourn time, or it decays into polonium while still on the cold baffle. In the first case, it can contribute again to the background rate.

This talk describes the simulation of the effectiveness of the radon suppression with the Test-Particle Monte Carlo (TPMC) code MolFlow+ and presents data from an extensive measurement program. The simulation takes the effect of the half-lifes of the different radon isotopes into account, as well as the temperature dependent sojourn time of radon on a cold surface. By comparing measured rates with TPMC simulations for different sojourn times (temperatures), we learned more about possible surface conditions of the baffles (Cu, Cu2O, H2O) and the corresponding desorption enthalpies. The measurements with the MS showed that the radon suppression with cold baffles works sufficiently well, so that the remaining background is no longer radon dominated. This work has been supported by the German BMBF (05A14VK2).

Summary

Short-lived radon isotopes are a serious source of background for the measurement of the neutrino mass with the KATRIN experiment. This talk describes a method to suppress the radon rate with cold baffles in the ultra-high vacuum chamber of the KATRIN Main Spectrometer and compares simulations with measured data. The effectiveness of the method depends not only on the half-life of the radon isotopes, but also on the temperature of the cryogenic baffles.

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