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Simulation of low-level tritium and radon background in the KATRIN main spectrometer

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The KArlsruhe TRItium Neutrino (KATRIN) experiment is a large scale experiment for the model independent determination of the mass of electron anti-neutrinos with a sensitivity of 200 meV/c^2. It investigates the kinematics of electrons from tritium beta decay close to the endpoint of the energy spectrum at 18.6 keV. Low statistics at the endpoint requires an equally low background rate below 10^-2 counts per second. The measurement setup consists of a high luminosity windowless gaseous tritium source (WGTS), a magnetic electron transport system with differential and cryogenic pumping for tritium retention, and an electro-static retarding spectrometer section (pre-spectrometer and main spectrometer) for energy analysis, followed by a segmented detector system for counting transmitted beta-electrons.

A major source of background comes from magnetically trapped electrons in the main spectrometer (vacuum vessel: 1240 m^3, 10^-11 mbar) produced by nuclear decays in the magnetic flux tube of the spectrometer. Major contributions are expected from short-lived radon isotopes and tritium. Primary electrons, originating from these decays, can be trapped for hours, until they have lost almost all their energy through inelastic scattering on residual gas particles. Depending on the initial energy of the primary electron, hundreds of low energetic secondary electrons can be produced, which are able to leave the spectrometer, adding to the background rate.

This talk will describe the simulation methods and presents results from simulations of various background sources. Decays of Rn-219, emanating from the main vacuum pump, and tritium from the WGTS that reaches the spectrometer account for most of the background. Although the radon is undergoing an alpha decay, electrons are emitted through various processes, such as shake-off, internal conversion and Auger electrons.

The simulation was done using the KASSIOPEIA framework, which has been developed for the KATRIN experiment for low energy electron tracking, field calculation and detector simulation. The results of the simulations have been used to optimize the design parameters of the vacuum system with regard to radon emanation and tritium pumping, in order to reach the stringent requirements of the neutrino mass measurement.

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