Simulation of Rarefied Gas Flow in the KATRIN Source

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Abstract

The KATRIN experiment at the Karlsruhe Institute of Technology (KIT) will measure the neutrino mass on a sub-eV range. Therefore the electron spectrum of the beta decay of Tritium will be detected and compared with a simulated spectrum of the used windowless gaseous Tritium source (WGTS).

In the WGTS (Figure 1) tritium is injected with 0.33Pa through small orifices in the middle of a 10m long tube with a diameter of 90mm held at a constant temperature of 30K. At the beam tube ends Tritium will be pumped in differential pumping sections (DPS) where high temperature gradients occur. A Tritium reduction factor of 107 will be reached at the end of this section that is followed by a cryogenic pumping section with another reduction factor of 107. The density profile in the WGTS and in the transport system is the main systematic uncertainty of the simulation of the WGTS electron spectrum. To generate an accurate simulation of the WGTS the density profile has to be known at a precision of 0.1% [1].
This is a challenging task as the gas flow regime changes from continuum flow in the injection region to transitional flow in the beam tube to molecular flow after the first pumping section [2].

This work presents the COMSOL Multiphysics® simulation of the density profile in the gas injection system, the beam tube (Figure 2) and the first pumping port using the transitional flow interface. Further transport and pumping sections are simulated using the molecular flow interface. Results will be compared with numerical calculations of Felix Sharipov [3-5].

Reference

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[4] F. Sharipov. „Tritium flow through a non-symmetrical source. Simulation of gas flow through an injection hole”. KATRIN internal Document. 2010.

[5] S. Pantazis, D. Valougeorgis, F. Sharipov. „Numerical simulation of end effects in the WGTS unit”. KATRIN internal Document. 2011.

Figures used in the abstract

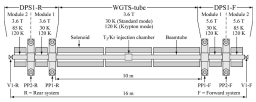

Figure 1: Scheme of the WGTS tube and first pumping sections

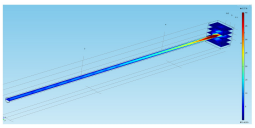

Figure 2: Simulation of bulk velocity [m/s] in the WTGS tube and in the first pumping chamber