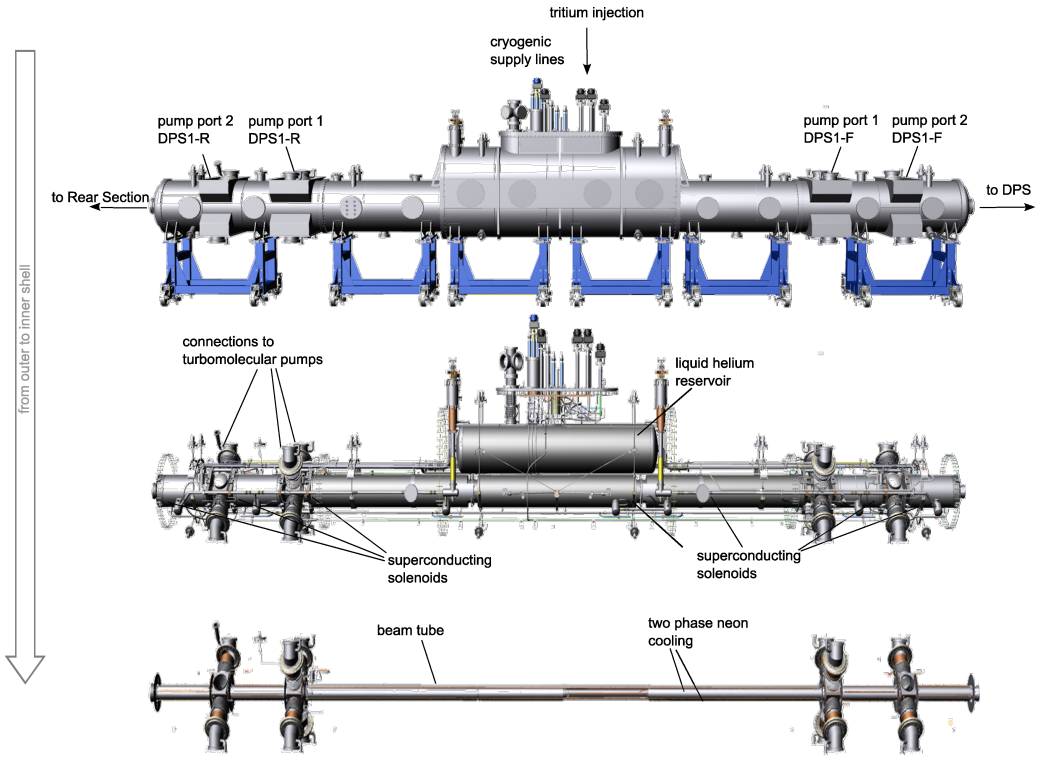
Bachelor/Master thesis:
Gas dynamics simulation of the KATRIN source section

The KATRIN experiment uses a Windowless Gaseous Tritium Source (WGTS) to generate a large flux of β-electrons (10^{11} Bq). The WGTS is essentially 10 m long steel tube where molecular tritium gas is injected in the center and pumped out at the sides. The three dimensional distribution of the tritium gas density depends on the gas flow regime and the exact geometry of the vacuum system. Precise knowledge about the shape of this density distribution is essential for modeling of source-related systematic effects (scattering of β-electrons on tritium molecules, magnetic trapping of β-electrons due to magnetic field inhomogeneities). Since the WGTS is a enclosed within a cryostat, and therefore difficult to access, the best method of obtaining the density profile is from simulation.



Description of tasks Past studies on this topic focus on the WGTS's operation for the active neutrino mass search. However, for the keV sterile neutrino search, the WGTS will be operated at a much lower pressure to reduce the rate at the detector, resulting in a different gas flow regime. Furthermore, the geometry of the vacuum system upstream of the injection point (towards the rear section) could previously be neglected. But for the measurement with TRISTAN the inclusion of the upstream geometry becomes a crucial aspect. The tasks of this thesis are therefore to assess at which gas flow regime the WGTS is operated for TRISTAN, and to determine the new shape of the tritium density profile towards both sides of the injection point using different kinds of simulation tools (Molflow+ and Comsol). Validation of the obtained pressure profile is possible at certain positions along the WGTS using pressure gauge readings and partial pressure information from mass spectrometers.

Karlsruhe Institute of Technology

Summary

- Scope: Bachelor (with adaption of content) or Master thesis
- Fundamental subject areas:
  Vacuum physics and technology, monte carlo simulation
- Outline / Structure:
  - Introductory training concerning KATRIN and the keV sterile neutrino measurement with TRISTAN, basics of vacuum technology, discussion of previous related studies, usage of simulation software
  - Determination of the gas dynamics regime for TRISTAN measurement at low tritium source gas density ($0.01 - 10\%$ of nominal setting)
  - Calculation of the 3D tritium gas density profile in the source and rear section with the appropriate simulation framework (Molflow+ / Comsol)
  - Validation of the simulation with pressure gauge and mass spectrometer readings from test measurements from KATRIN's source section at an appropriate gas density
  - Master: Extension of the simulation to include vacuum design studies concerning a modified rear section for the second TRISTAN physics run in 2027
- Helpful skills: Python (or similar) for analyzing simulation results
- Location: Building 402 on KIT Campus North
- Commencement: April 2024
- Scientific support, advisors, and contact:
  - Prof. Dr. Guido Drexlin / Prof. Dr. Kathrin Valerius
  - Dr. Joachim Wolf (joachim.wolf@kit.edu)
  - Dr. Martin Descher (martin.descher@kit.edu)