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Results of the first Cool-down of the KATRIN Cryogenic Pumping Section

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Abstract. The **K**arlsruhe **T**ritium **N**eutrino (KATRIN) experiment uses the kinematics of tritium β -decay to determine the effective neutrino mass with a sensitivity of $m_\nu = 200 \text{ meV}/c^2$ (90% C.L.). In order to measure the decay electrons it is important to guide them adiabatically from the source to the spectrometer. In addition the diffusion of tritium into the spectrometers from the source has to be reduced by 14 orders of magnitude as tritium inside the spectrometers would induce additional background. For these two tasks the transport and pumping section were constructed. The last part of this section is the **C**ryogenic **P**umping **S**ection (CPS), which aims to reduce the residual gas flow by more than seven orders of magnitude. For this a cold argon frost surface, with a $\approx 2 \text{ m}^2$) area that is maintained at 3 K, will be prepared to adsorb the incoming tritium molecules.

Before the whole KATRIN setup will be connected together the performance of CPS will be tested on its own. This poster presents the measurement results of the first cool-down of the CPS.

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1. Introduction

The aim of the **K**arlsruhe **T**ritium **N**eutrino (KATRIN) experiment is to determine the effective neutrino mass with an unsurpassed sensitivity of $m_\nu = 200 \text{ meV}/c^2$ (90% C.L.) by measuring the spectrum of the tritium β -decay. The KATRIN setup can be divided into two parts, the source and transport section and the spectrometer and detector section. In the first section gaseous tritium is injected into a windowless gaseous tritium source (WGTS). The decay electrons are transported adiabatically through the differential pumping section (DPS) and the cryogenic pumping section (CPS) into the spectrometer section. Using the MAC-E filter method, only electrons with sufficient high energy will pass the potential barrier and will be counted in the detector [1].

The CPS has to achieve two different tasks for the KATRIN experiment. One is to guide the beta electrons adiabatically through the CPS. The other one is the reduction of the tritium flow from the source side toward the spectrometer by at least seven orders of magnitude. The high suppression factor is mandatory to keep the background induced by radioactive decays in the main spectrometer on the mHz level [2]. To realize the adiabatic transport of the electrons the CPS consists of seven superconducting magnets. The second and fourth magnets are tilted by 15° so that neutral tritium molecules will hit the wall and will be absorbed on a 3 K cold cryo pump with an argon frost layer. The main requirements for this pump are a high pumping speed for tritium per surface unit (specific pumping speed), a long term tritium retention at



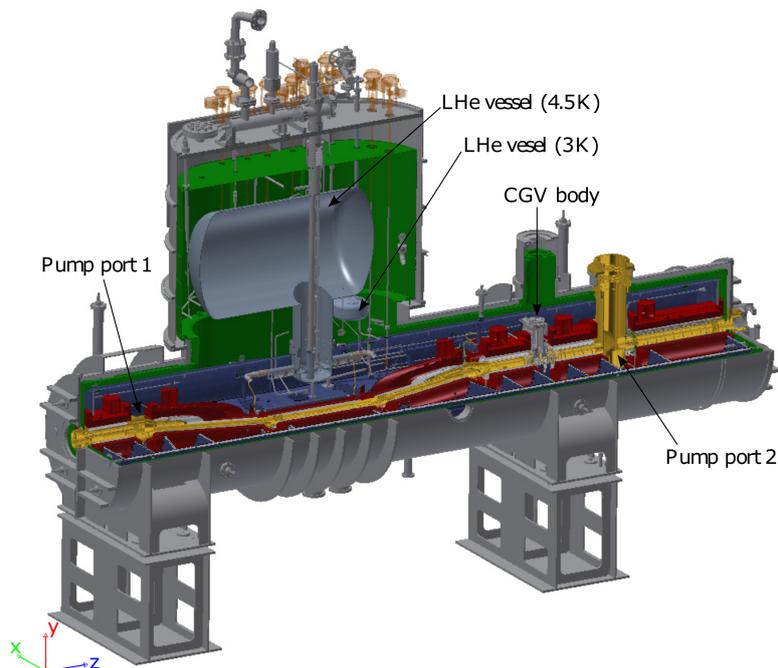


Figure 1. The schematic of the CPS assembly is shown. The gold plated beam tube is surrounded by seven superconducting magnets (in red). The LHe vessels, which are required for the cooling of the magnets and beam tube, are displayed in light blue. Between pump port 1 and the cold gate valve (CGV), the argon frost layer will be prepared and kept at 3 K. The cold gate valve (CGV) is a safety valve operated inside the CPS at a temperature of 4.5 K. On pump port 2 the forward beam monitor and the condensed krypton source will be attached. The differential pumping section (DPS) will be on the left side, the prespectrometer on the right side.

operation conditions and an easy and complete removal of the tritium at stand-by conditions (regeneration). The long term retention is directly correlated to the mean sojourn time:

$$\tau = \tau_0 \cdot \exp\left(\frac{E_B}{RT}\right) \quad (1)$$

where τ_0 is the adsorbed particle's period of oscillation perpendicular to the surface ($\approx 10^{-13}$ s), E_B is the binding energy for one mole of adsorbed gas, T the operation temperature and $R = 8.314$ J/K·mol. For this reason low temperatures of the Argon frost ($E_B = 1200$ J/mol) pump are highly desirable.

2. Results of the first cool-down

To achieve a tritium mass flow reduction of at least seven orders of magnitude the beam tube elements 2-5 are cooled down to 3 K in operation mode. After the arrival of the 12 ton cryostat in Karlsruhe in July 2015, all the mechanical and measurement, control and regulation (MSR) installations had been finished in April 2016. The first cool-down of the CPS started on May 11, 2016. To do so the cryostat has a nitrogen (77 K) and helium loop (5 K, 5 bar), which are used to cool down the superconducting magnets and the beam tubes actively. In figure 2

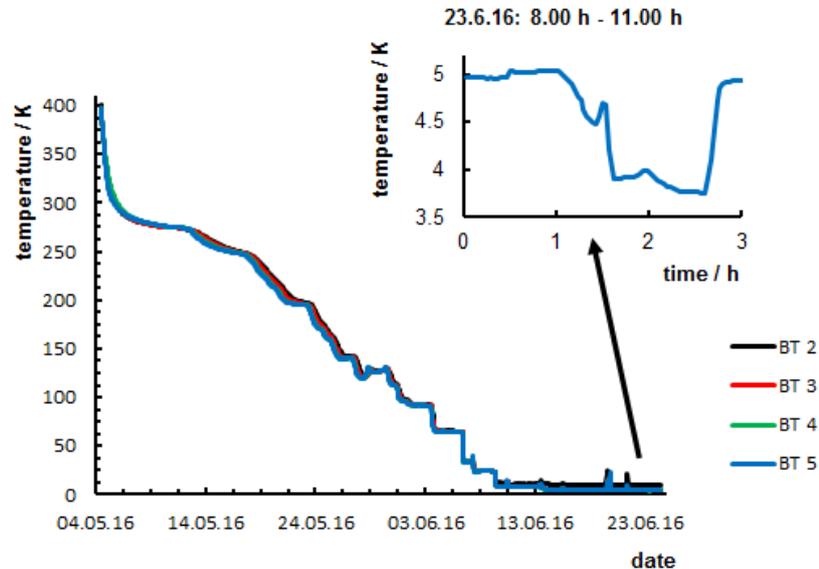


Figure 2. The temperature in Kelvin is plotted over the time. On the bottom left the temperature of the beam tube elements 2-5 are shown from the beginning of cool down until 23th June. On the top right a three hour test of the 3 K cooling of beam tube 3 is presented.

the development of the temperature of the sections 2 to 5 is displayed. After 35 days stable temperatures of 5 K were reached. To get a temperature below 5 K the 3 K LHe cooling has to be turned on. This is achieved by a heat exchanger whose vapour pressure of the liquid helium bath is pumped down to 250 mbar. The targeted beam tube temperature of 3 K has not been achieved yet, and further investigations are in progress. However, as shown in the inset of figure 2 the functionality of the 3 K system has been demonstrated. Long term operation of the system will improve stability and performance.

Also the magnets have been tested for the first time and a magnetic field of 5.4 T was accomplished. With the successful test of the quench detector system the ability to transport the electrons adiabatically through the CPS was shown.

3. Conclusion

The cryogenic pumping section is an important component in the KATRIN experiment, which aims to determine the electron antineutrino mass. To keep the background induced by radioactive decays in the spectrometer in the mHz regime, the tritium flow must be reduced in the CPS cryostat by seven orders of magnitudes through cryosorption. First engineering runs prove the cooling principle of the CPS beam tube sections significantly below the 5 K-level of the refrigerator supply.

References

- [1] Beamson G *et al* 1980 *J. Phys. E* **13** 64
- [2] Mertens S *et al* 2013 *Astropart. Phys.* **41** 52-62