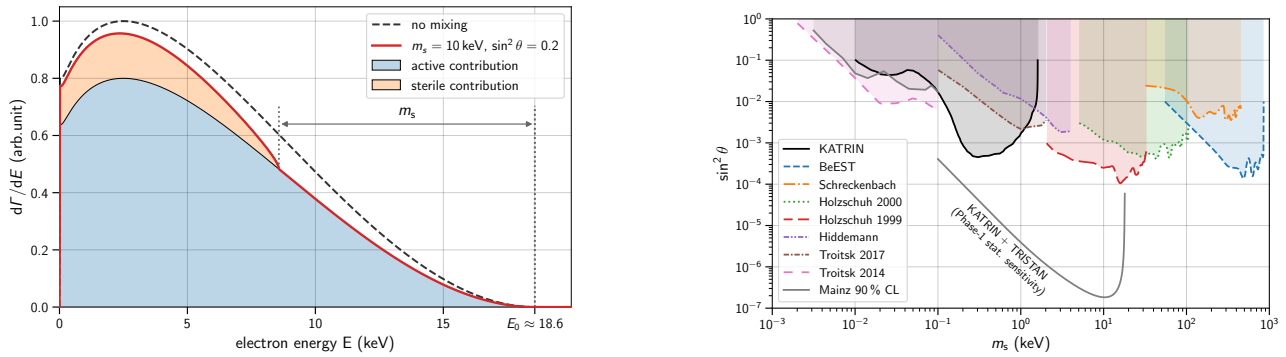
Master and Bachelor thesis topics for KATRIN + TRISTAN

at the Institute for Astroparticle Physics at KIT

Introduction

Starting in 2026, the KATRIN experiment will conduct a high-statistics measurement of the differential tritium β-spectrum to energies deep below the kinematic endpoint. This enables the search for keV sterile neutrinos with masses less than the kinematic endpoint energy $m_4 \leq E_0 = 18.6\,\mathrm{keV}$, aiming for an unprecedented statistical sensitivity of $|U_{e4}|^2 = \sin^2\theta \sim 10^{-6}$ for the mixing amplitude. The differential spectrum is obtained by decreasing the retarding potential of KATRIN's main spectrometer, and by determining the β-electron energies by their energy deposition in the new TRISTAN silicon drift detector (SDD) array (see figure 2).



(a) Sterile neutrino signature

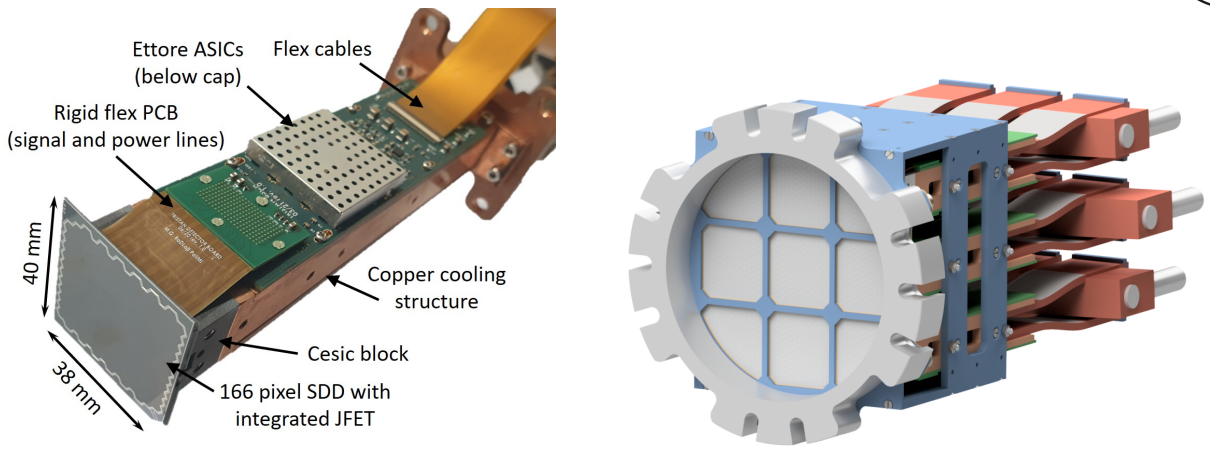
(b) Laboratory limits

Figure: Sterile neutrino signature in β-decay with exaggerated mixing amplitude (a), and existing laboratory limits in the sterile neutrino parameter space (b).

The development of the new detector is almost complete, but many test measurements concerning detector characterization, integration into the KATRIN beamline, and the investigation of systematic effects are work in progress. The preparations are now entering the final stages before the keV sterile neutrino search begins. Since there is still much to do, we are always looking forward to new people joining the effort, and we offer many (hopefully exciting) topics for bachelor and master theses.

Sterile neutrinos with keV mass

In the Standard Model of Particle Physics (SM) neutrinos are assumed to be massless, in spite of contrasting observations from neutrino oscillation experiments. The reason for this incompleteness of the SM is that the particular mechanism for generating the appropriate mass terms is yet unknown. One natural and theoretically well-motivated way of obtaining those mass terms is the extension of the SM with right-handed neutrinos. This type of neutrino would react even rarer in weak interactions and is thus called *sterile*, while the known flavors are referred to as *active*. The existence of sterile neutrinos could resolve several open questions concerning the SM neutrino sector and cosmology, such as the smallness of the neutrino masses, the dominance of matter over anti-matter in the universe, or the question of whether neutrinos are their own antiparticles. Compared to active neutrinos, sterile neutrinos could be considerably more massive, and with a mass on the keV scale, they turn out to be excellent candidate particles for Dark Matter.



(a) TRISTAN module

(b) TRISTAN Phase-1 detector

Figure: TRISTAN module (a), and the Phase-1 detector consisting of 9 modules (b).

Work environment

The members of the KATRIN collaboration who prepare the measurement with TRISTAN are spread across multiple universities and institutes (KIT in Karlsruhe, TUM + HLL in Munich, PoliMi + UniMiB in Milano, SUT + Chula in Thailand, WWU in Münster ...). Accordingly, the work environment is highly international with KIT as the central location hosting the experiment at the renowned Tritium Laboritory Karlsruhe.

At KIT, the main focus for TRISTAN is on everything related to the KATRIN beamline: Integration of the TRISTAN detector in the detector section, optimization of the electromagnetic field design, mitigation of beamline-related systematic effects (rear wall backscattering, detector back reflection, source scattering, ...) and associated hardware modifications (upgrade of post acceleration electrode, exchange of rear wall, adjustment of main spectrometer magnetic field).

Due to the immediate proximity to the experiment, we offer topics related to hardware tasks, as well as data analysis and simulation studies. The largest part of the local KATRIN group (this also includes everyone working on the currently ongoing neutrino mass measurement and other aspects of KATRIN) is in building 402 on Campus North (here we have a plenty available office space and a lively community). Further members of the local team are in building 601 (workshop and test labs) and in in building 451 (tritium laboratory).

Topics & Contact

For specific pre-defined topics see dedicated topic handouts (contacts in summary on backside). In case of general interest for a thesis about the keV sterile neutrino measurement at KATRIN contact:

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