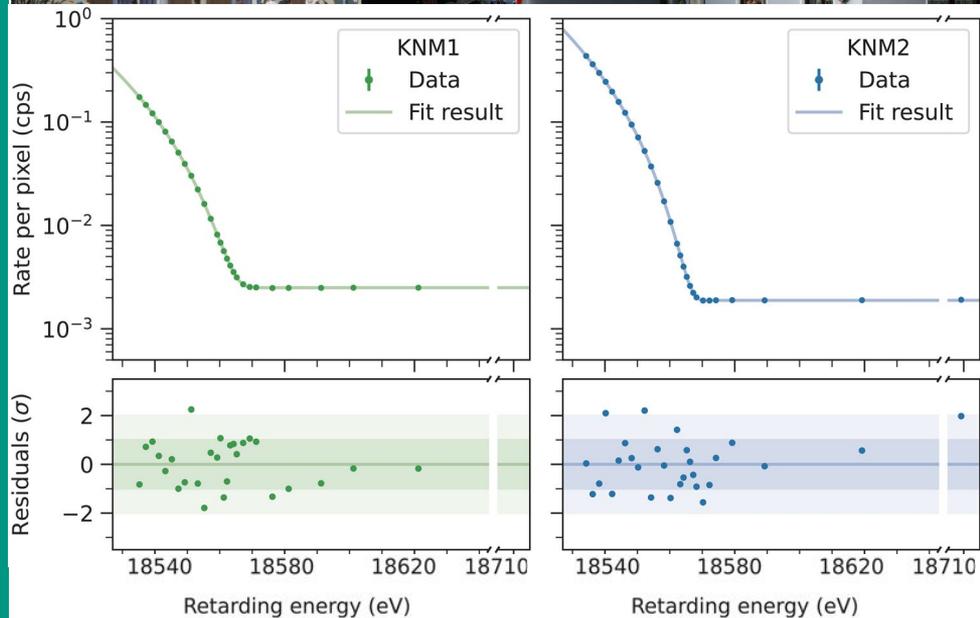


KATRIN experiment

Master & Bachelor

Contact: markus.steidl@kit.edu ; alexey.lokhov@kit.edu

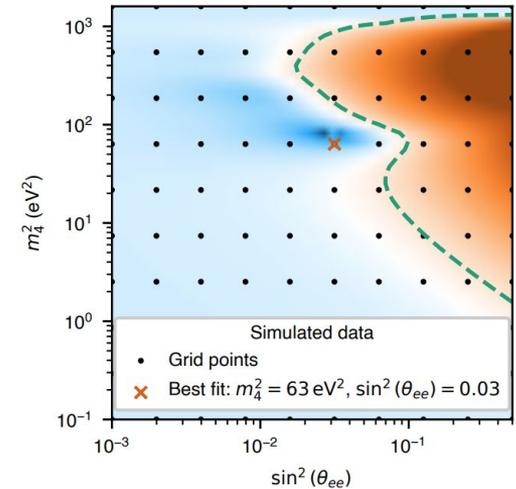
02.02.2026



Sensitivity of the KATRIN Experiment to eV-Scale Sterile Neutrinos

KATRIN searches for light sterile neutrinos by looking for a spectral distortion (a kink) in the high-energy tail of the tritium β spectrum. Using 36 million β -decay electrons collected in 259 days (KNM1–5), KATRIN excluded substantial regions of parameter space relevant to the gallium anomaly and challenged other claimed signals. The KNM1–5 sterile analysis describes a grid-scan (shape only) analysis, Wilks-theorem usage with Monte-Carlo validation, campaign-wise combination and [Material and Reference](#) projected 1000-day sensitivity.

KNM6 (and later campaigns) are available for analysis and future campaigns will increase statistics and reduce backgrounds, improving sterile sensitivity. This provides an opportunity to (1) extend the sterile search to KNM6+ data; and (2) investigate analysis improvements (systematics, pixel-wise strategies, Wilks validity, optimized Region Of Interest) to reach the projected KATRIN sensitivity.



Focus: Data analysis and sensitivity projection

Where: Campus North, B402, KATRIN

Supervisors: Alexey Lokhov

1st referent: Prof. Kathrin Valerius.

Start: Ready to start

Contact: aleksei.lokhov@kit.edu

Data combination for final KATRIN neutrino mass analysis

Contact: aleksei.lokhov@kit.edu
karo.erhardt@kit.edu

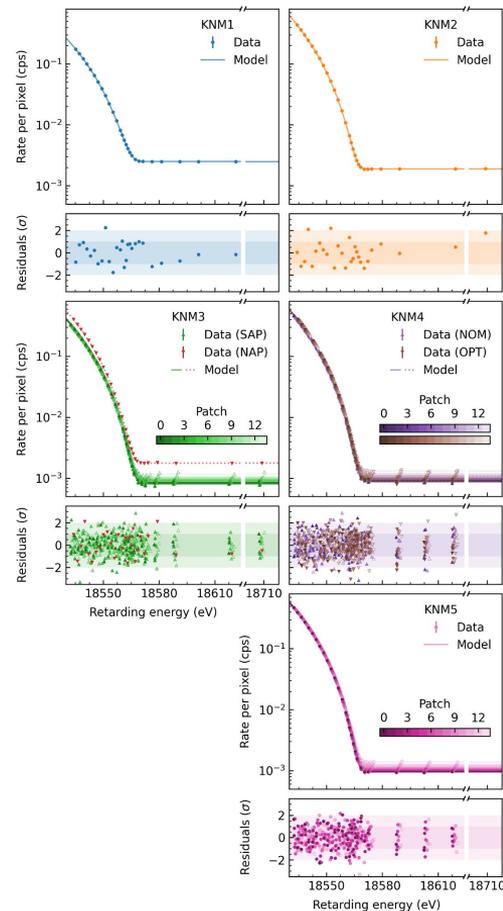
Soon 1000 days of beta scans are recorded, but there will be no neutrino mass result without careful analysis.

The simultaneous analysis of individual scans is too challenging, so scans recorded under similar conditions are combined in the analysis and described by the same model.

The goal of the thesis is to study different options of data combinations and quantify possible impact on the neutrino mass estimation, to analyze the calibration data and propose data combination scenarios. This work has great relevance for the final neutrino mass analysis.

For this seemingly theoretical Data Analysis task, the understanding of the Experiment and its systematic effects will be crucial and in the focus of the work.

Supervision: Karo and Alexey ,where?: Campus North, B402 , Ready to start!



Investigation of electron emission from the inner spectrometer surface

One of the major factors limiting the sensitivity of the KATRIN experiment on the neutrino mass is an elevated background rate due to an accumulation of ^{210}Pb on the inner spectrometer surface. A series of dedicated measurements to study the emission of electrons from the spectrometer surface was performed throughout the operation of KATRIN. The scope of this master thesis is a detailed analysis of these data sets, including simulations of electric and magnetic fields. Depending on the timing of the thesis, participation in a final measurement campaign is possible.



Focus: Data analysis and simulation of electric and magnetic fields

Where: Campus North, B402, KATRIN

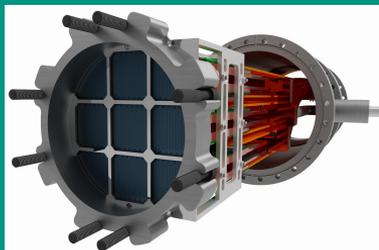
Supervisors: Florian Fränkle

Start: ready to start

Contact: florian.fraenkle@kit.edu

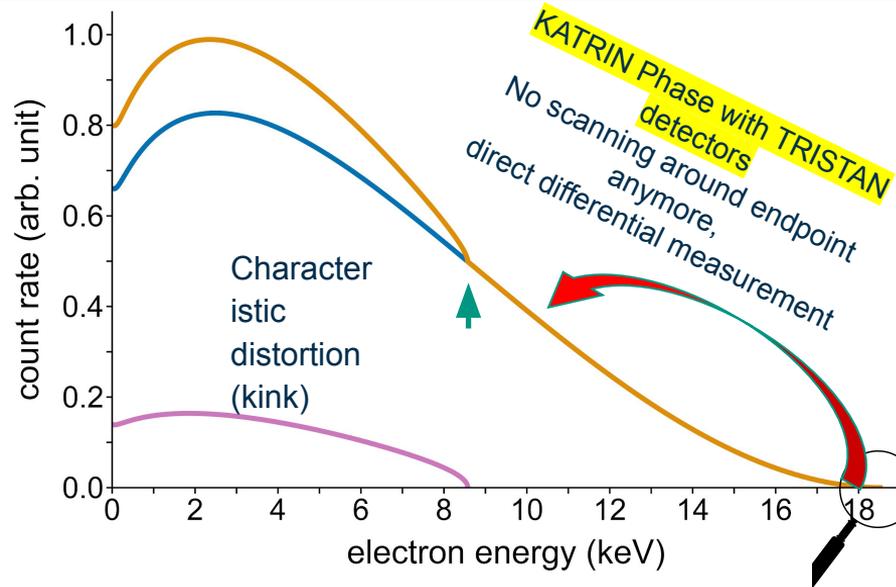
KATRIN with TRISTAN Detectors

Master & Bachelor

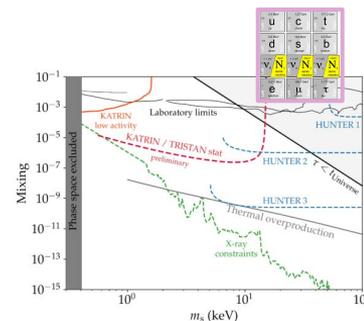


Contact: Markus Steidl, Dominic Hinz
markus.steidl@kit.edu & dominic.hinz@kit.edu

02.02.2026



- Perform most precise beta-spectrum ever (10^{14} counts)
- Improve world leading laboratory limits on sterile keV neutrinos (<18 keV) by a factor of >100 w/o astrophysical assumptions



Status of preparations at KIT

Current status

- General concept of the new detector section works
- Specifications of new detector section for vacuum & cryo achieved
- Prototype detectors in operation
- First selection with new IPE-DAQ (Tile Main Board) was successful
- First promising results for post-acceleration
- Move to beamline in May 2026

Outlook

- **Endurance tests of post-acceleration with a detector module**
- **Detailed characterization of DAQ (Tile MainBoard and Backend)**
- **From March 2026: operation with 9 modules**



Master thesis topics - KATRIN with TRISTAN detectors

The work is embedded in the group “KATRIN R&D” at IAP and fully within the KATRIN collaboration. Participation in the local group meeting (Mo. 14:00, in presence) and an international call (Wed. 14:00, virtual) is required. Office space is located at B402, typically 10 to 15 KATRIN team members join daily the office in an open, friendly and international environment. Presentations in English are mandatory.

We can adapt topics and find specific solutions. Contact markus.steidl@kit.edu or dominic.hinz@kit.edu . Referent is Prof. Kathrin Valerius.

Simulations of detector responses and comparison to data

(Experimental work and analysis)

Background investigations for the search of sterile keV neutrinos

(Experimental work and analysis)

Development of a GUI for the new Data Processing of KATRIN data

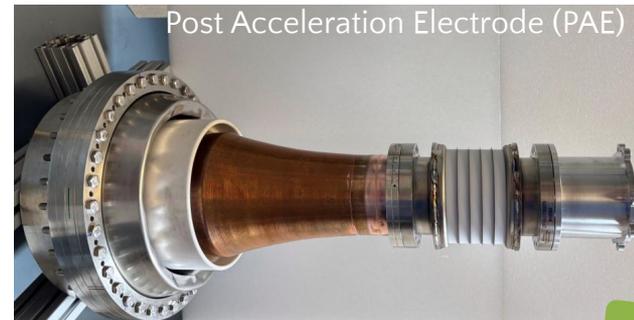
(Data processing in collaboration with Institute for Electronics and Data Processing)

Performance tests and investigations of the new FPGA based data-taking system

Experimental work, strongly focused on hardware, strongly connected to IT processes)

Simulations of detector responses and comparison with data

In order to achieve a better signal-to-background ratio, electrons at KATRIN are accelerated by +10 kV in front of the detector. Due to the high magnetic field used to guide the electrons, this is technologically challenging, as smallest Penning traps can dynamize into macroscopic and destructive discharges. After intensive work, the KATRIN team has developed a new post-acceleration line +20 kV potential.



The simulation of the detector responses are crucial to understand the data (detector responses). For this purpose a dedicated simulation framework has been established and is ready to be used and improved. In collaboration with our Phd students you will compare existing data with your simulations. You will check the level of agreement and deduce from that required improvements for KATRINs search for the sterile keV neutrino.

Focus: Experimental work (25%) and Analysis (75%)

Where: Campus North, B402 and B601, KATRIN R&D Group

Supervisors: Roman Hiller as well as participating doctoral students

Start: ready to start

Contact: roman.hiller@kit.edu

Background investigations for the search of sterile keV Neutrinos

For the search for ppm signals in the tritium spectrum, the control and understanding of a number of different systematic effects is critical. One of them is the natural background in the data coming from radioactive impurities in the proximity in the detector and cosmic induced events. Due to the intense KATRIN tritium source and therefore expected excellent signal-to-background ratio, this background has not been assessed yet in detail and has been treated in our sensitivity studies in a very simplified way so far.



The aim of the thesis is to improve the background treatment in the sensitivity studies.

Also, comparisons of the background of the new TRISTAN detectors to the former Focal Plane detectors are scheduled.

Focus: Experimental work (20%) and Analysis (80%)

Where: Campus North, B402 and B601, KATRIN R&D Group

Supervisors: Florian Fränkle as well as participating doctoral students

Start: any time

Contact: florian.fraenkle@kit.edu

Development of a pulsed LED-based calibration method for TRISTAN detectors

For the search for ppm signals in the tritium spectrum, a precise calibration of the detector is important. This is achieved by using several calibration sources, in particular radioactive sources and artificial electron sources (e-guns). In this thesis, we want to expand the portfolio to include pulsed LED or pulsed laser-based methods. This potentially allows new methods to monitor changes of the detector surface (by using different wavelengths) and determine so-called pile-up effects (by generating a high rate of optical pulses with precisely known rate).



Contact: rudolf.sack@kit.edu

The aim of the thesis is to work and try out different options for implementing these methods into the standard calibration routine for the TRISTAN detectors.

Focus: Experimental work (70%) and Analysis (30%)

Where: Campus North, B402 and B601, KATRIN R&D Group

Supervisors: Rudolf Sack as well as participating doctoral students

Start: requires 2 months preparation time at our side (purchase of hardware)

Performance tests and investigations of the new FPGA based data-taking system for KATRIN

The differential measurement method of the entire tritium spectrum is challenging for the data processing. We expect more than 6 orders of magnitude of increased data. This means a redesigning of the entire data processing and using a new data acquisition system (DAQ). This has been developed over the last 5 years at the Institute for Data Processing and Electronics (IPE) and Max-Planck Institutes. The new system is ready for use.



In this work, you intensively characterize and test the performance of the DAQ system. For example, you will examine long term stabilities. You will also support to combine the new processing chain of the data with existing analysis tools of the collaboration. In this work, enjoyment and ideally, previous knowledge, of IT processes are an advantage. This work is in close cooperation with the Max-Planck-Institute for Nuclear Physics, Heidelberg. Regular participation in a virtual meeting (Fri. 11:00) is required.

Focus: Experimental work (50%) and Analysis (50%)

Where: Campus North, B402 and B601, KATRIN R&D Group

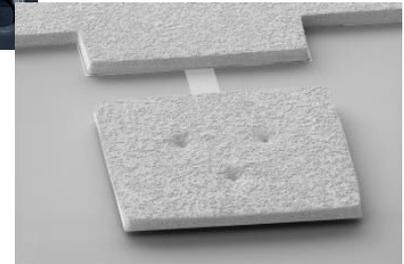
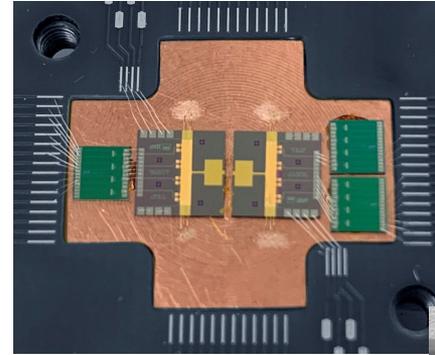
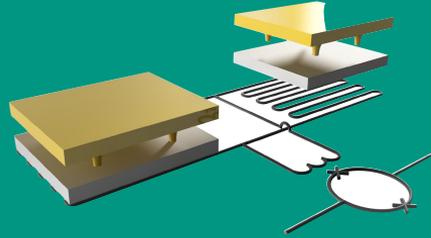
Supervisors: Markus Steidl, Sascha Wüstling (IPE), Andrew Gavin (MPIK Heidelberg)

Start: Oct-Nov

Contact: markus.steidl@kit.edu

Quantum Sensors for KATRIN++

Master & Bachelor



Contact: Markus Steidl (IAP) markus.steidl@kit.edu
Sebastian Kempf (IMS) sebastian.kempf@kit.edu

KATRIN++ - sensitivity studies for a next-generation neutrino mass experiment

Work breakdown:

This thesis is part of the active research & development phase for a future neutrino mass experiment to further close the gap to lower limits given by theory.

In our group we're developing a new software package to help planning a next-generation neutrino mass experiment by translating future potential experimental setups into the sensitivity on the neutrino mass one can achieve with these.

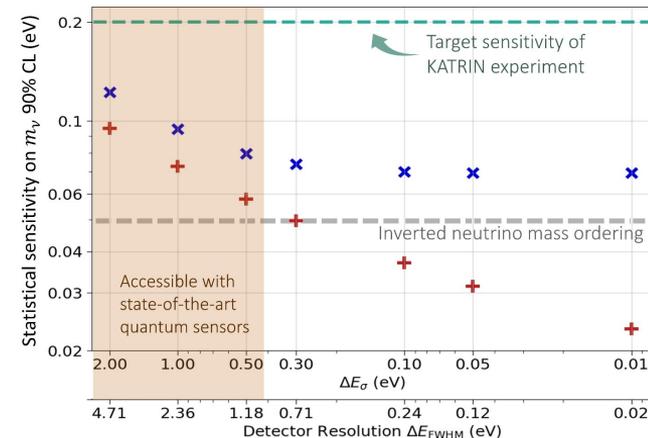
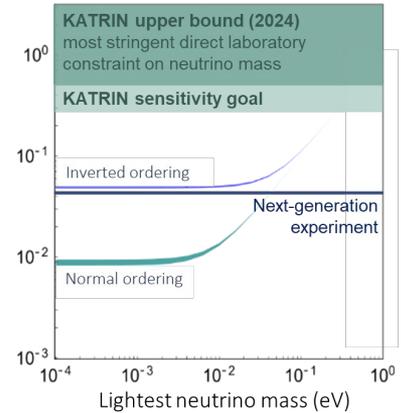
Focus: software development and data analysis

Where: Campus North, B402 in the KATRIN Analysis group

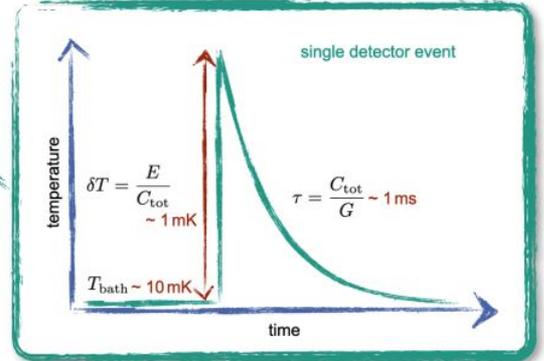
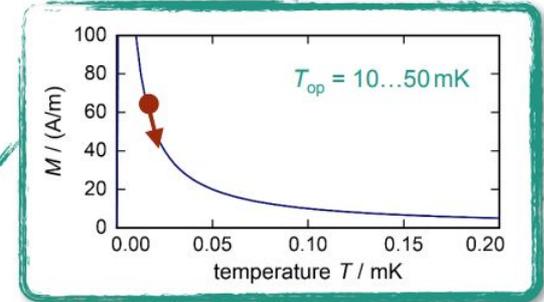
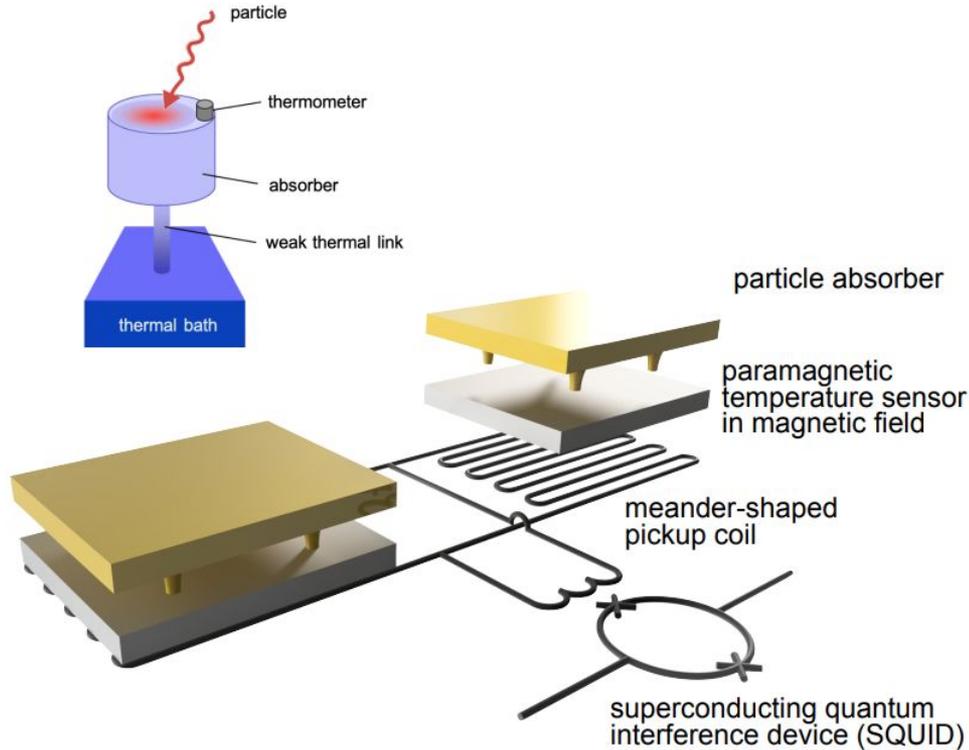
Supervisor: Svenja Heyns & Prof. Dr. Kathrin Valerius

Start: anytime

Contact: svenja.heyns@kit.edu

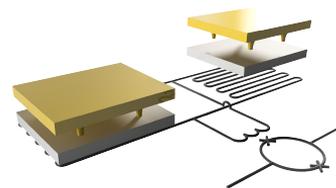


Magnetic microcalorimeters



Precision probe tritium beta decay

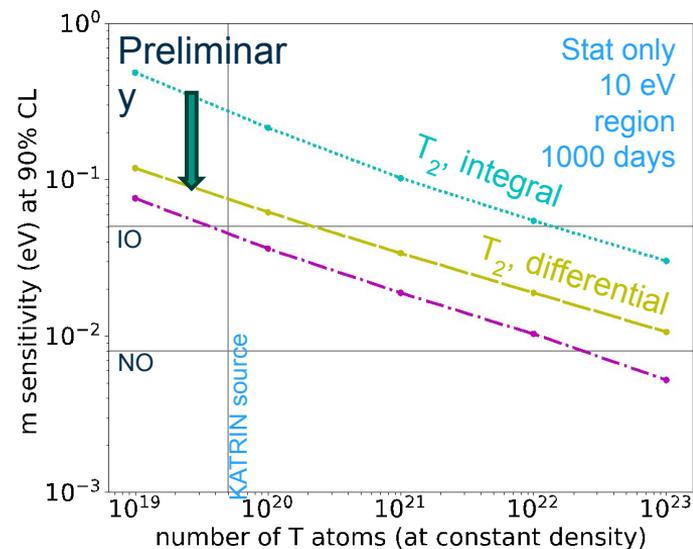
2019-2025: Integral MAC-E filter technology



Sensitivity improvement on observable m_ν^2 by a factor ~ 20

Challenges of coupling quantum sensor detector array to KATRIN infrastructure

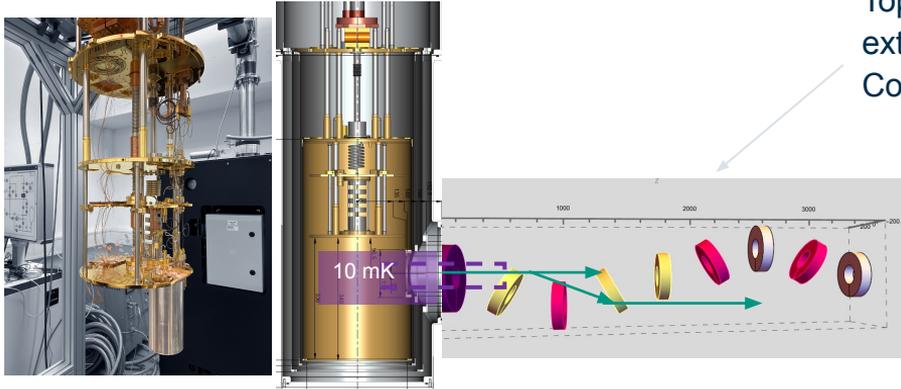
- Type of quantum sensor
- Operation in magnetic field (~ 10 mT)
- Coupling of mK cryo-platform with RT spectrometer
- Large area detector and multiplexing of $\sim 1e6$ channels
- Limits to energy resolution



Master thesis topics - Quantum sensors for KATRIN++

- *The work is embedded in the group “KATRIN R&D” at IAP and within the KATRIN collaboration. Participation in the local group meeting (Mo. 14:00, in presence) and a monthly international call (Mon. 14:00, virtual) is required.*
- *Office space is located at B402, typically 10 to 15 KATRIN team members join daily the office in an open, friendly and international environment. Presentations in English are mandatory.*
- *The work is in very close cooperation with the group of Prof. Sebastian Kempf at the IMS (currently Campus West). Integration into the group “KATRIN R&D” at IAP, as well at the group at IMS is required.*
- *1st referent is Prof. Kathrin Valerius.*

MMCs in strong magnetic fields (IAP, IMS)



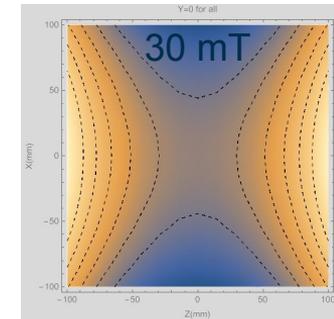
Topic 1: Setup, simulations and tests of a magnetic chicane to couple external instruments to a 10mK- dilution refrigerator

Contact: markus.steidl@kit.edu

Topic 2: Performing and analyzing measurements of MMC in an external magnetic field

(at IMS, AG Kempf, Campus West)

Contact: michael.mueller2@kit.edu



40 mT

Topic 1: Thermal simulations of a magnetic chicane to couple external instruments to a 10mK- dilution refrigerator

Work breakdown:

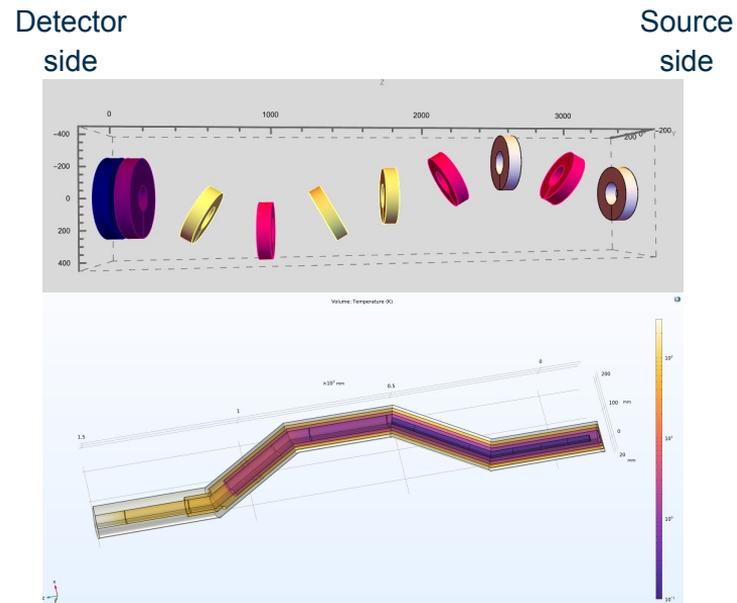
- 1) Setup geometries of a world-wide unique instrument in COMSOL
- 2) Determine by simulation heat loads on components
- 3) Determine safety budgets for cryogenic design under different assumptions for material properties.

Focus: Experimental work (10%) and Analysis, Simulation (90%)

Where: Campus North, B402 and B601, KATRIN R&D Group in close cooperation with engineering group

Supervisor: Markus Steidl

Start: at any time



Very first COMSOL simulations

Contact: markus.steidl@kit.edu

Topic 1: Design and realization of a detector system to validate magnet tracking simulations

Work breakdown:

A technical challenge to couple quantum sensors to the KATRIN beamlines remains the setup of a magnetic chicane realizing the thermal transition from room temperature to Milli-Kelvin. To validate the magnetic tracking simulations we set up a teststand consisting of an electron gun and a two-dimensional detector system to check the tracking pattern through the chicane.

for material properties. Your task will be to realize and commission the source-detector system for such tests.

Focus: Experimental work (50%) and Analysis, Simulation (50%)

Where: Campus North, B402 and B601, KATRIN R&D Group in close cooperation with engineering group

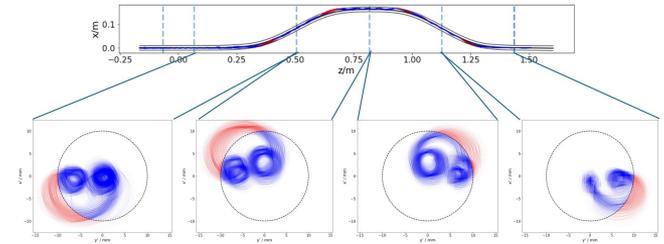
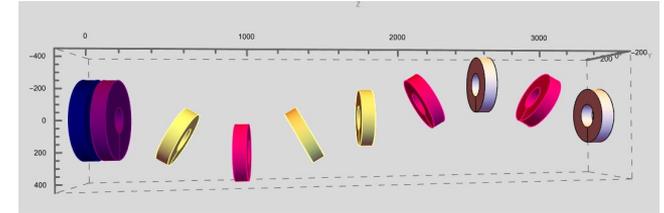
Supervisor: Markus Steidl

Contact: markus.steidl@kit.edu

Start: notification 2–3 months in advance, that hardware can be prepared.

Detector side

Source side



Electron trajectories through chicane - to be validated by experiment.

Topic 2: Performing and analyzing measurements of MMC in an external magnetic field.

Work breakdown:

- 1) Training in operation of MMCs and dilution refrigerators
- 2) Measurement campaign (typically 1-2 weeks)
- 3) Data analysis
- 4) Modelling of detector responses
- 5) Optimizing setup
- 6) In parallel: Sensitivity studies for neutrino mass measurements using MMCs

Focus: Experimental work (50%) and Analysis (50%)

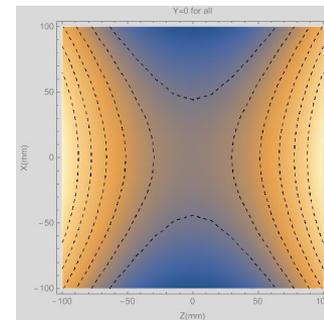
Where: Campus West, IMS, groups of Prof. Kempf, Campus North, B402, KATRIN R&D Group (IAP)

Supervisor: Markus Steidl (IAP) & Michael Müller (IMS)

Start: whenever you are ready



Test setup existing and commissioned, first measurements taken



Field calculations of air coil

Contact: markus.steidl@kit.edu
michael.mueller2@kit.edu

Topic 3: Development and Characterisation of Tritium-Loaded Metal Samples using Next Generation Metallic Microcalorimeters (MMCs)

Work breakdown:

- 1) Loading of metallic samples with Tritium
- 2) Safety tests of tritium outgassing from the prepared samples
- 3) Measurement of the samples using next generation metallic microcalorimeters
- 4) Modeling of the energy loss electron experience traveling through the metal
- 5) Analysis of the measured data

Focus: Experimental work (50%) and Analysis (50%)

Where: Tritium Laboratory Karlsruhe (TLK), groups of Dr. M. Schlösser, Institute of Micro- and Nanoelectronic Systems (IMS), Group of Prof. Sebastian Kempf

Supervisor: Neven Kovac (IAP) & Alexandra Becker (IAP) & Magnus Schlösser (TLK), Sebastian Kempf (IMS), Kathrin Valerius (IAP)

Start: September–October (maybe November is possible as well)

Contact: neven.kovac@kit.edu

