HELMHOLTZ Matter

NEWS SHEET

Programs:
Matter and the Universe
Matter and Technologies
From Matter to Materials and Life

April 2025

$m_\nu < 0.45\ eV/c^2$

KATRIN sets new limit:

Neutrinos 1 million times lighter than electrons

M. Zacher/KATRIN-Kollaboration

Neutrino Mass

Helmholtz Matter investigates the structure and properties of matter. Now the KATRIN collaboration is presenting its latest result on neutrino mass.

Neutrinos play a key role both in the universe and in the world of fundamental particles, as they connect cosmic and subatomic scales: As remnants of the Big Bang, neutrinos still permeate our cosmos in large numbers - they are billions of times more abundant than atoms. As "cosmic architects", they have helped shape the development of the universe.

Their small but non-vanishing rest mass goes beyond the established standard model of elementary particle physics. It has not yet been possible to measure the neutrino mass directly in the laboratory.


Markus Breig/KIT

The world-leading KArlsruhe TRItium Neutrino experiment (KATRIN), which measures the neutrino mass using a direct and model-independent method, has now succeeded in determining an upper limit of 0.45 eV/c² for the neutrino mass.

Science 388 (issue 6743), 180-185 (2025)

"The new result is a milestone on the way to KATRIN's measurement target."

Kathrin Valerius
Co-Spokesperson
KATRIN Collaboration
Karlsruhe Institute
of Technology (KIT)

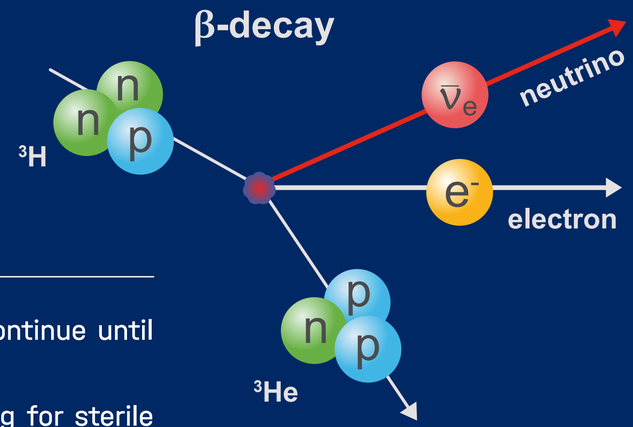
The KATRIN Experiment

The KATRIN measurement is based on the work of W. Pauli and E. Fermi, who showed almost 100 years ago that precise beta decay spectroscopy can make the tiny neutrino mass visible. KATRIN analyzes the decay of the hydrogen isotope tritium into ^{3}He in order to determine the neutrino mass from the energy distribution of the beta electrons. To do this, KATRIN needs a powerful tritium source operated at the Tritium Laboratory Karlsruhe (TLK). Measurement operations have been running since 2019 and will continue until the end of 2025.

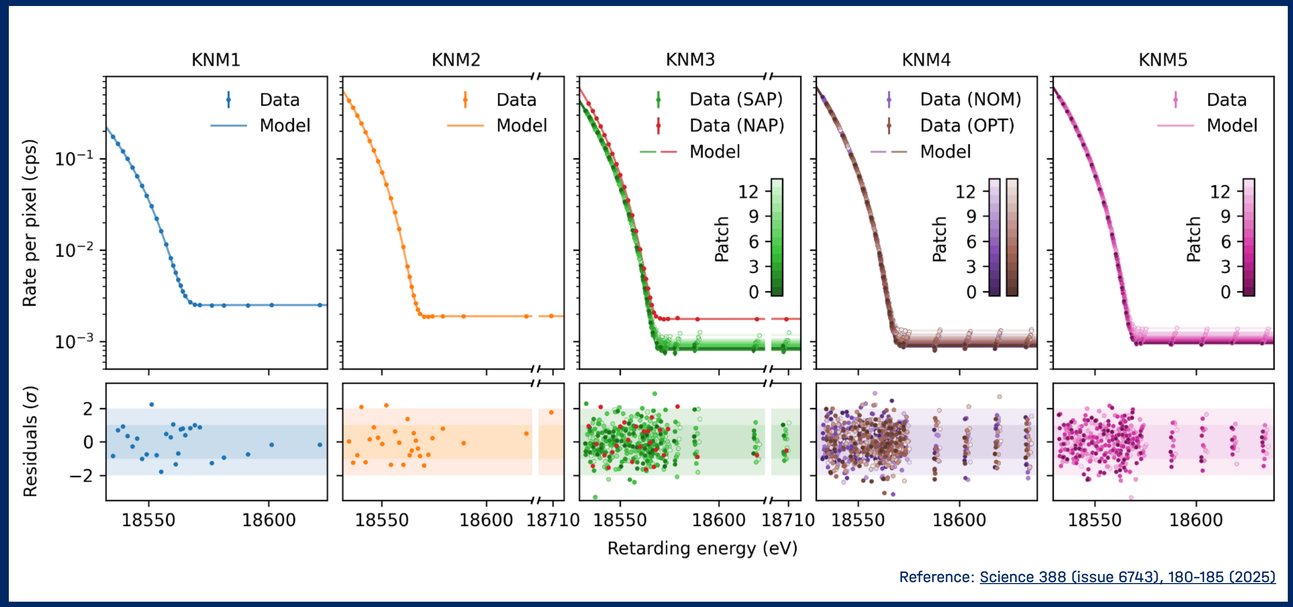
From 2026, KATRIN will be searching for sterile neutrinos in the keV mass range. Such sterile neutrinos are potential candidates for the mysterious dark matter that has been detected in numerous astrophysical and cosmological observations, but whose exact nature is still unknown.

Based on the recently presented evaluation of the first five science runs (KNM 1-5, image on the right), a new upper limit for the neutrino mass could be determined.

This model-independent laboratory method allows KATRIN to narrow down the mass of these "lightweights of the universe" with unprecedented precision. This allows cosmological models to be tested and new insights to be gained.



Precision spectroscopy of tritium decay with the first five runs of the KATRIN measurements.



Reference: Science 388 (issue 6743), 180-185 (2025)

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The Centers of Helmholtz Matter:

DESY.

KIT Karlsruhe Institute of Technology

JÜLICH Forschungszentrum

GSI

HZB Helmholtz Zentrum Berlin

Helmholtz-Zentrum hereon

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Legal notice:

Facts and Figures

KATRIN Experiment

- Length: 70 m
- Width: 12.6 m
- Height: 12.6 m (main spectrometer with magnetic coils)
- Weight: approx. 250 tons

Tritium Laboratory Karlsruhe TLK

- Missions: Fuel cycle for nuclear fusion and measurement of neutrino mass
- Handling license for 40 g tritium
- > 30 years of experience in safe handling of tritium
- World's largest infrastructure for civilian tritium use
- > 20 glove box systems on more than 1600 m² of laboratory space

KATRIN Collaboration

150 researchers from more than 20 institutions in 7 countries:
Czech Republic, France, Germany, Italy, Spain, Thailand, USA

German Participation

HU Berlin, U Bonn, U Heidelberg, U Mainz, U Münster, TU Munich,
U Wuppertal, KIT, MPIK Heidelberg, MPP Munich

Location

KIT Campus North, Karlsruhe
www.katrin.kit.edu

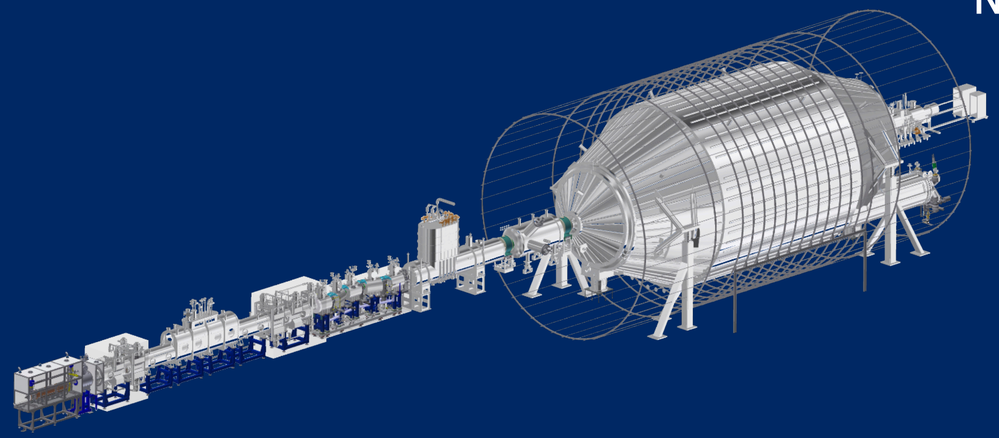
Helmholtz Programs

Matter and the Universe, Matter and Technologies

Contact

KIT Karlsruhe Institute of Technology

kathrin.valerius@kit.edu



Research Goal

Neutrinos shape the development of our universe. However, their properties and nature still raise many unanswered questions. Determining the neutrino mass is a crucial mission for cosmology, astrophysics and particle physics.

KATRIN helps us to better understand the universe.

Beatrix von Puttkamer/KIT