TRISTAN: a novel detector for keV-sterile neutrino search with KATRIN

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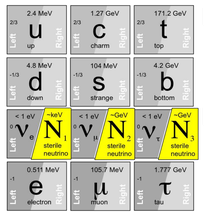
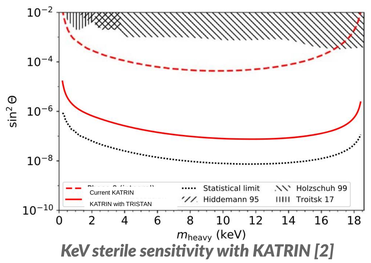
NEUTRINO 2020

keV-sterile neutrinos



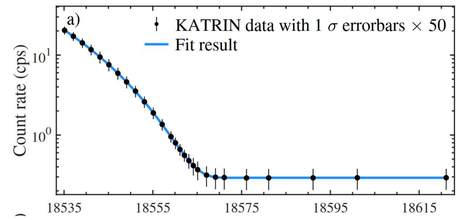
- **Sterile neutrinos** are a **minimal extension** to Standard Model
- **keV-sterile neutrinos** are viable **dark matter** candidates



KeV sterile sensitivity with KATRIN [2]

The KATRIN experiment

- MAC-E filter β-spectrometer located in Karlsruhe, Germany
- **Neutrino mass measurement** by investigating the tritium endpoint region
- First results published last year [1]

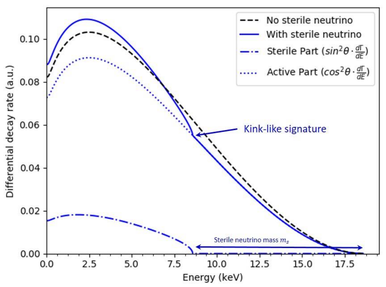


Tritium endpoint region as measured by KATRIN [1]

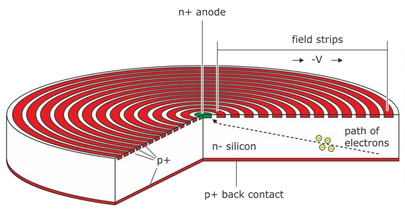
The TRISTAN project

Concept

- Search for **keV-sterile neutrino** in the entire tritium beta spectrum using KATRIN spectrometer.
- Imprint is a **kink-like signature**
- Sensitivity on mixing angle of 10^{-6} [2]



Requirements

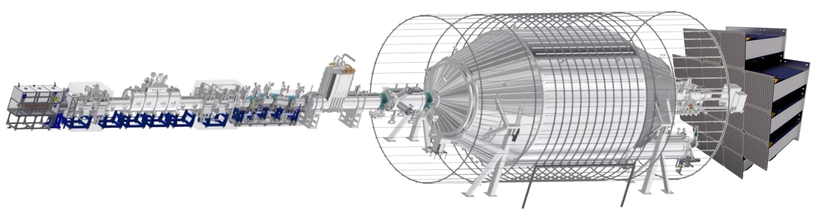


- Energy resolution : FWHM 300 eV@20 keV
- Large area of coverage : 20 cm
- Low energy threshold for electrons : ~1 keV
- Handling high rates : 10^8 cps

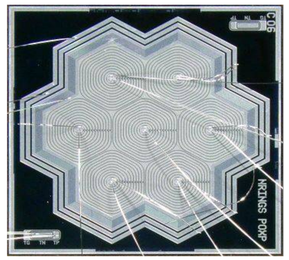
→ **Silicon Drift Detector** technology

Projet

Development of a novel detector and read-out system for the KATRIN spectrometer, made of 21 modules for a total of 3486 SDD pixels.



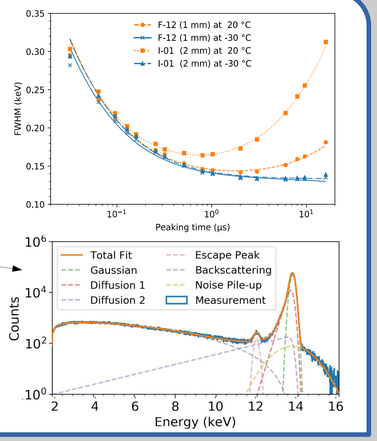
Prototype



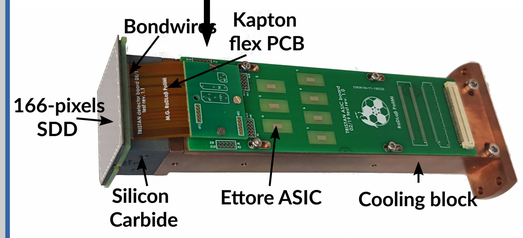
7 pixels TRISTAN SDD (Back side)

7 pixels, Ø 2 mm, hexagonal, external CMOS (CUBE)

- **Resolution :** 140 eV FWHM @ 6 keV
- **Threshold :** ~ 300 - 500 eV
- **Count Rate :** up to 10^5 Hz/pixel
- **Dead layer** measured using ^{87}Kr and Electronic microscope **: < 50 nm**
- **Response to photons [2] and electrons [3]** using Monte Carlo and empirical functions
- **Applications** : on keV-sterile with Troitsk[4] and as the KATRIN Forward Beam Monitor detector



Module

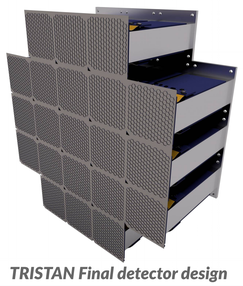


TRISTAN Module design

166 pixels, Ø 3 mm, integrated nJFET

- **Operating 1/21 final detector with realistic conditions**
- Stable **cooling** system (-40°C, Silicon carbide material)
- **Vacuum** (no outgasing, standing 10^{-10} mbar)
- Structure on construction now[5], expected end of this year
- Implementation in KATRIN as Monitor Spectrometer detector,
- Dedicated ASIC developed for TRISTAN SDD (Ettore) [6]

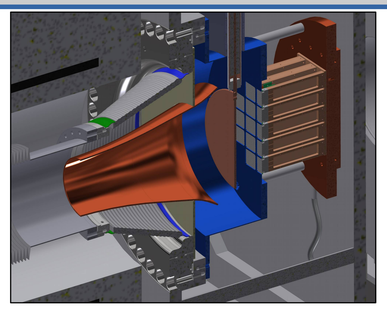
Final detector



TRISTAN Final detector design

21 modules, ~3500 pixels

- New detector chamber for KATRIN
- Design a dedicated DAQ with full waveform digitalization
- Implementation planned after the mass campaign
- Post-acceleration electrode 30 kV
- Systematics studies on DAQ non linearities, charge sharing, backscattering effects



Design of the KATRIN detector chamber

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[1] M. Aker et al. (KATRIN Collaboration), *An improved upper limit on the neutrino mass from a direct kinematic method by KATRIN*, PRL 123, 221802 (2019)
[2] S. Mertens et al., *A novel detector system for KATRIN to search for keV-scale sterile neutrinos* , Journal of Phys. G, 46-6, (2019)
[3] M. Lebert et al., *Characterization of Silicon Drift Detectors with Electrons for the TRISTAN Project,* arxiv :2003.04756, (2020)
[4] T. Brunst et al., *Measurements with a TRISTAN prototype detector system at the "Troitsk nu-mass" experiment in integral and differential mode,* JINST 14 P11013 (2019)
[5] P. Trigilio et al., *ETTORE: a 12-Channel Front-End ASIC for SDDs with Integrated JFET*, IEEE NSS/MIC, pp. 1-4 (2018)
[6] T. Houdy et al., *Hunting keV sterile neutrinos with KATRIN: building the first TRISTAN module*, J. Phys.: Conf. Ser. 1468 012177 (2020)