TRISTAN Detector Upgrade for the KATRIN Experiment

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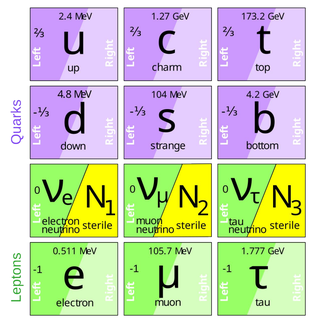
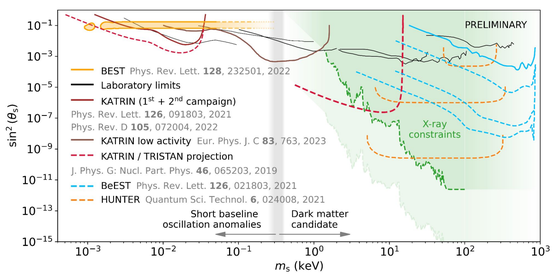
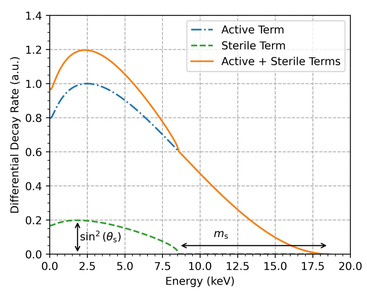
Search for Sterile Neutrinos

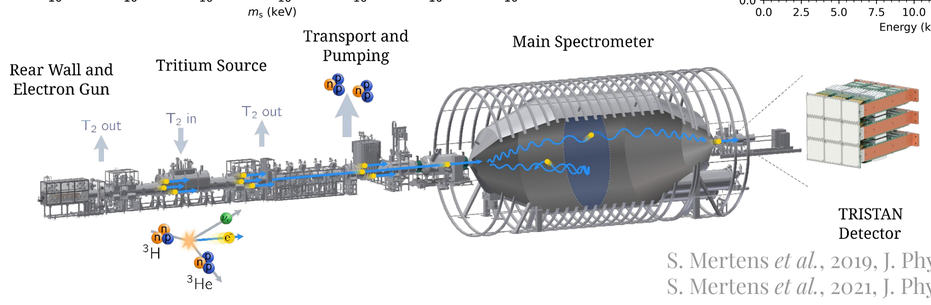
- Sterile neutrinos in keV-mass range: Dark Matter candidate
- Use KATRIN source and beamline to search for keV-scale sterile neutrinos in single β-decay
- New detector required for high-resolution β-spectroscopy at high count rate

⇒ TRISTAN Detector





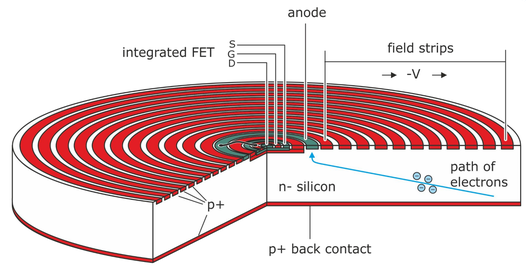




S. Mertens *et al.*, 2019, J. Phys. G 46, 065203
S. Mertens *et al.*, 2021, J. Phys. G 48, 015008

Silicon Drift Detector

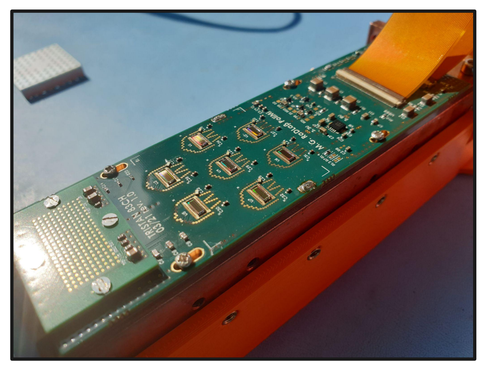
- Low anode capacity (~170 fF)
- High rate capability (100 kcps/px)
- Excellent energy resolution (300 eV FWHM for 20 keV electrons)



⇒ TRISTAN Detector is a multi-pixel Silicon Drift Detector (SDD)

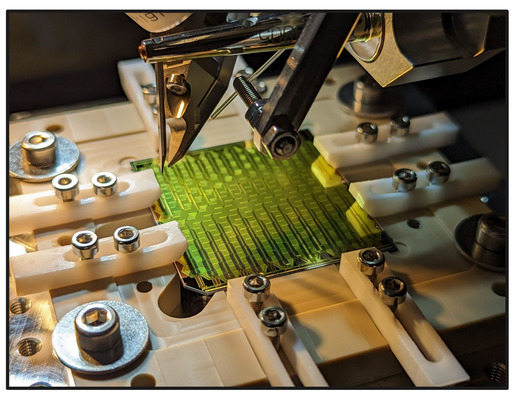
P. Lechner *et al.*, 1996, Nucl. Instrum. Methods Phys. Res. A, 377
P. Lechner *et al.*, 2001, Nucl. Instrum. Methods Phys. Res. A, 458

- Challenges:
  - Scaling to focal plane array (> 1000 pixels)
  - Difficult environment (UHV/XHV, magnetic fields, etc.)
  - Understanding the detector response to electrons
- Readout:
  - Charge sensitive pre-amplifier
  - ETTORE: 12-channel low-noise ASIC
  - DAQ development by KIT-IPE

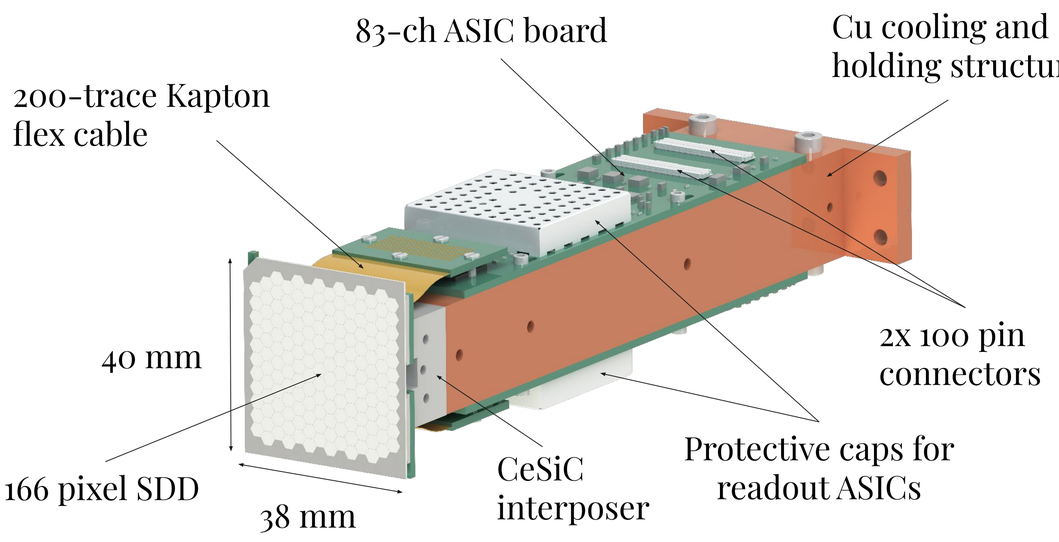


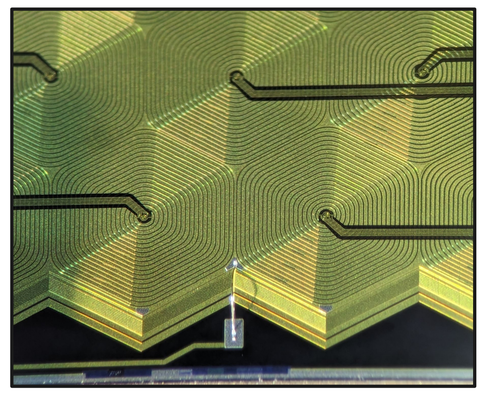
P. Trigilio *et al.*, 2018, IEEE NSS/MIC, 8824675

TRISTAN Detector Module



Wire bonding of SDD

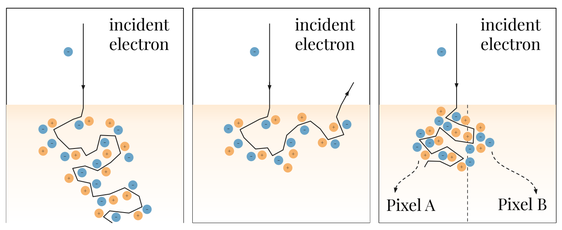




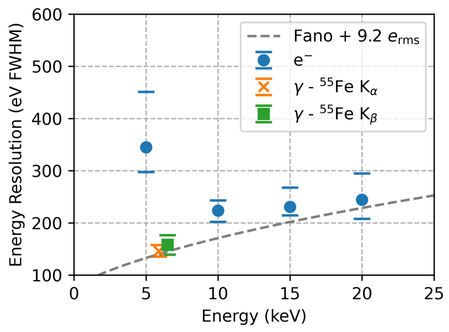
Close up of individual pixels

M. Gugiatti *et al.*, 2020, NIM A 979 164474
D. Siegmann *et al.*, 2024, arXiv 2401.14114

Characterization with Electrons



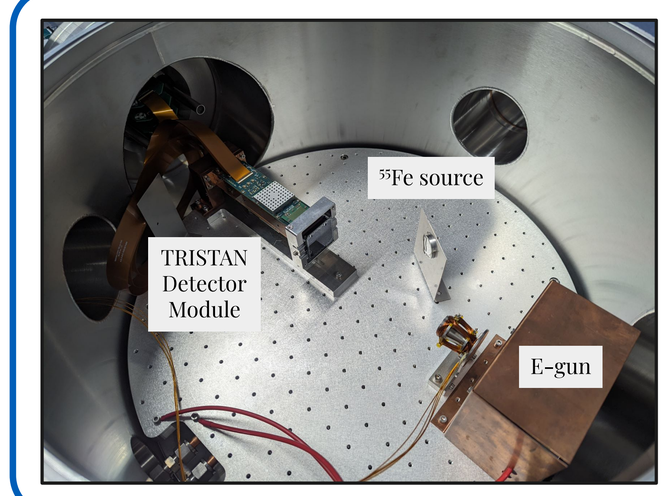
entrance window effect | back-scattering | charge sharing

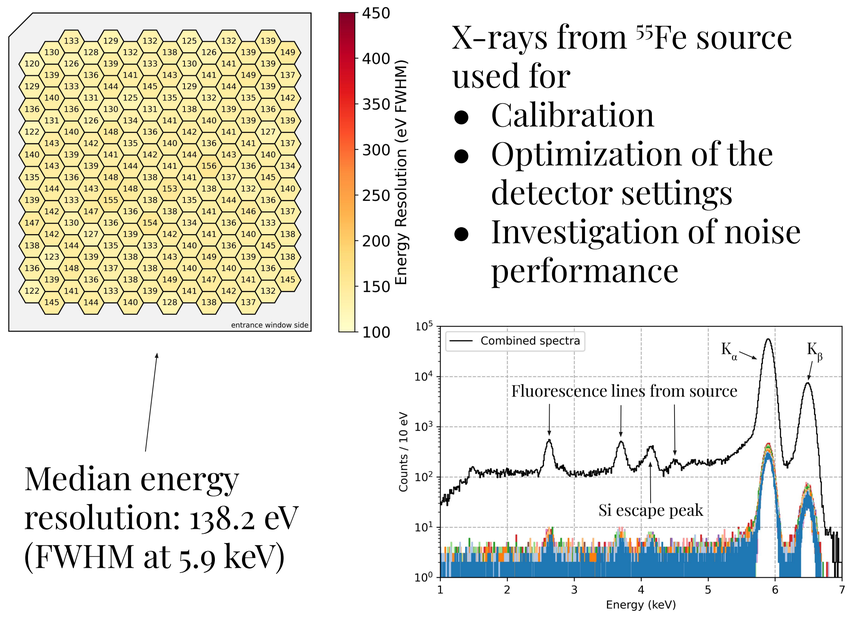


Temperature at SDD: -35°C

D. Spreng *et al.*, 2024, [In preparation]
C. Forstner *et al.*, 2024, [In preparation]

Characterization with X-Rays





Outlook

- Production and characterization of nine detector modules
- Integration into the KATRIN beamline (starting 01/2026)
- Development of precise response model including all relevant systematic uncertainties