

# TRISTAN: A novel detector for searching keV-sterile neutrinos at the KATRIN experiment

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### Motivation

Search for new particles in  $\beta$ -decay

$\sin^2\theta=0.2$   $m_4 = 10$  keV  
 Probability density [ $\text{eV}^{-1}$ ]  
 $E$  [keV]

light active neutrino  
 heavy sterile neutrino

KATRIN experiment

gaseous tritium source with up to  $10^{11}$  decays per second

M. Aker et al. (KATRIN Collaboration) 2019 Phys. Rev. Lett. 123 (22) (doi: 10.1103/PhysRevLett.123.221802)  
 M. Aker et al. (KATRIN Collaboration) 2021 JINST 16 T08015 (doi: 10.1088/1748-0221/16/08/T08015)

**New detector required for high rate  $\beta$ -spectroscopy: TRISTAN**

S. Mertens et al 2019 J. Phys. G: Nucl. Part. Phys. 46 065203 (doi: 10.1088/1361-6471/ab12fe)

### TRISTAN SDD

- High rate capability (total  $10^8$  cps)
- Good intrinsic energy resolution

**Multipixel silicon drift detector (SDD)**

7-pixel prototype

**Challenges:**

- Scaling to focal plane array (>1000 pixels)
- Electron spectroscopy (thin deadlayer)
- Difficult environment (UHV, magnetic fields etc.)

### Readout Chain

SDD pixel

ETTORE ASIC

vacuum air

DAQ system

ADC

ADC code ( $10^3$  lsb)  
 time (ms)

ADC code ( $10^3$  lsb)  
 time ( $\mu$ s)

ADC code ( $10^3$  lsb)  
 time (ns)

10% to 90%  
 risetime:  $\sim 50$  ns

**Preamplifier: ETTOR, 12-channel low noise ASIC**

P. Trigliolo et al., 2018 IEEE Nuclear Science Symposium and Medical Imaging Conference Proceedings (NSS/MIC), 2018, pp. 1-4 (doi: 10.1109/NSSMIC.2018.8824675)

### Electron Response

Hot-cathode electron source setup

$U = -16$  kV  
 $U = 0$  kV

50  $\mu$ m tantalum wire

detector

Precise measurement of electron response is very important for TRISTAN

Measured spectrum at  $U = -16$  kV

main peak FWHM: 350 eV  
 $^{55}\text{Fe}$  X-rays for calibration  
 Si escape peak  
 backscattering tail

counts  
 energy (keV)

S. Mertens et al 2021 J. Phys. G: Nucl. Part. Phys. 48 015008 (doi:10.1088/1361-6471/abc2dc)

### Multi-pixel-effect: Charge Sharing

Distribution of splitting ratio  $\eta$

pixel border  
 $E_{\text{pixel A}}$   $E_{\text{pixel B}}$   
 $\eta = E_{\text{pixel A}} / (E_{\text{pixel A}} + E_{\text{pixel B}})$

• No significant charge is lost at saddle point between pixels  
 • Measured Gaussian charge cloud size:  $\sim 14 \mu\text{m}$

Charge sharing events in an  $^{55}\text{Fe}$  measurement

energy pixel B (keV)  
 energy pixel A (keV)  
 number of events per  $70 \times 70 \text{ eV}^2$

### Multi-pixel-effect: Crosstalk

amplitude (a.u.)  
 time ( $\mu$ s)

physical event  
 crosstalk

• differential effect within vertical readout columns  
 → Better electrical separation between readout lines needed

trigger pixel number

plotted pixel number

1 2 3 4 5 6 7  
 1 2 3 4 5 6 7  
 time ( $\mu$ s)

### Outlook: 166-pixel module

2x100 pin connectors  
 200-trace Kapton flex cable  
 wire-bonds  
 83-channel ASIC board  
 copper block  
 CeSiC interface  
 166-pixel SDD

First operation of a 47-pixel module

counts ( $\times 10^3$ )  
 readout side

**Milestones:**

- ✓ First successful operation of a 47-pixel detector module
- Next step: Operation of a full 166-pixel detector module