A flexible setup for low-energy electron measurements of interest to neutrino physics

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on behalf of the ASPECT-BET collaboration

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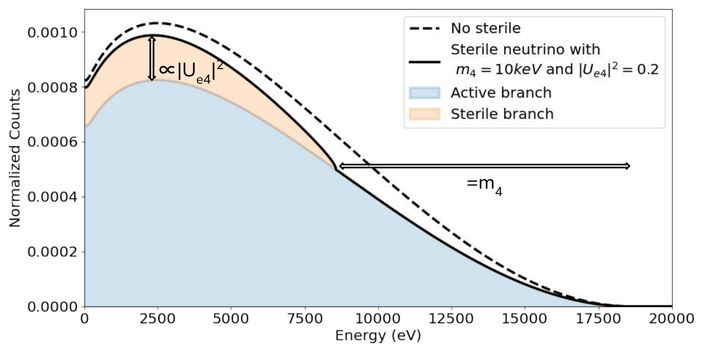
Importance of differential low-energy electron measurements

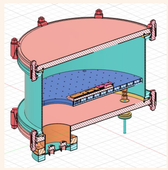
keV sterile neutrino search with KATRIN [1]:
- Dark Matter candidate
- need differential measurement of tritium β spectrum
- possible with upgraded detector: Silicon Drift Detector (SDD) matrix → TRISTAN [2]

Forbidden β spectra shape:
- discriminate between different nuclear theories
- important for 0νββ and reactor neutrino experiments
- can be measured using SDDs → ASPECT-BET [3]

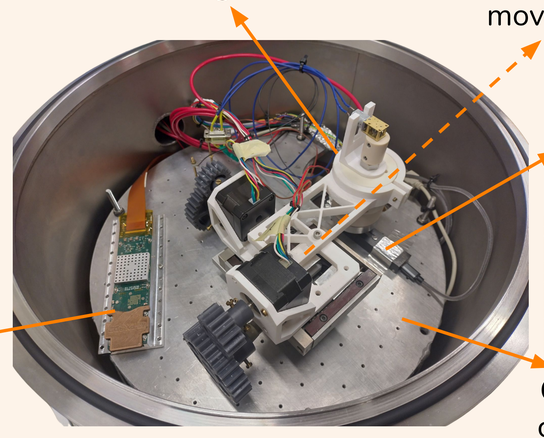
SDDs are widely used for X-ray spectroscopy, need to understand their response to low-energy electrons



dedicated test-stand @ MiB



Vacuum @1e-5 mbar with TMP

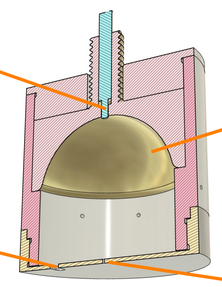


Digitization with 8ch CAEN DT5743

Electron gun working principle

Al source (work function ~4.2eV) @HV

UVC LED (275nm → 4.5eV) on anode



Gold-coated (work function ~5.1eV) hemispherical cathode @HV

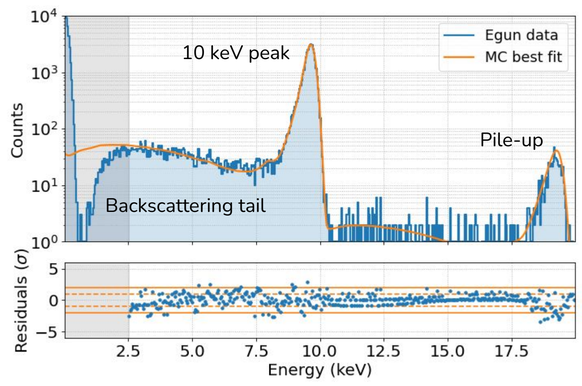
Collimation hole (adjustable 0.1-1 mm)

→ **photoemission of electron from Al, accelerated to eHV**

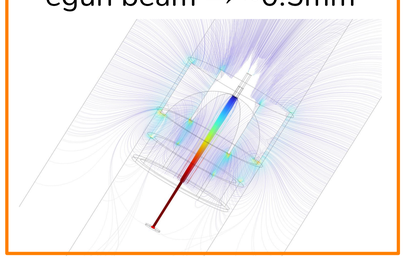
SDD response to monochromatic electrons

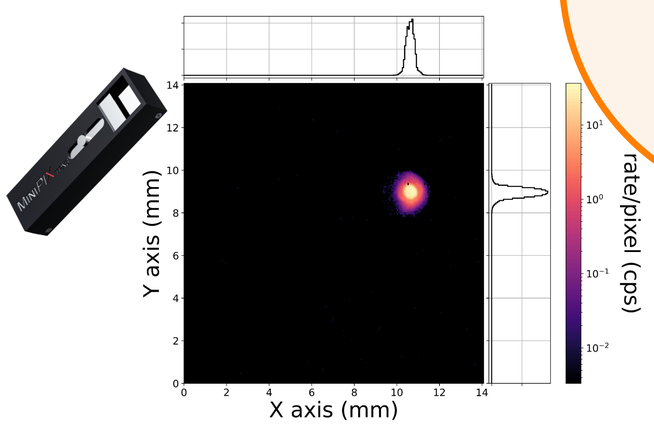
- shoot directly on SDD
- no border effects due to egun small beam spot
- possibility to study detector entrance window (EW) [4]
- electron response knowledge fundamental for keV-sterile search

Good agreement with GEANT4 simulations + empirical model for EW



COMSOL simulation of the egun beam → ~0.5mm

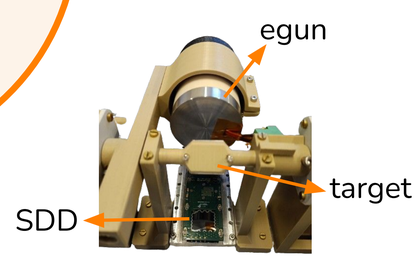




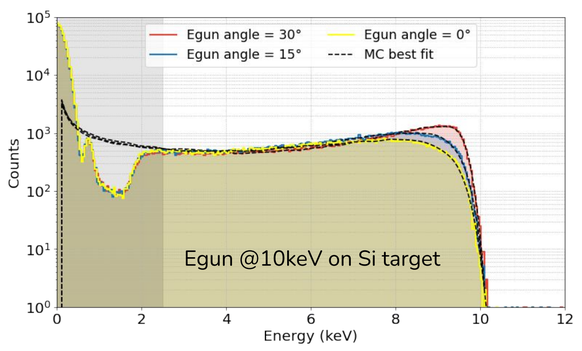
Measurement with Timepix3:

- **beam FWHM~0.5mm**
- **rate O(1000) electrons/s**

Backscattering measurements

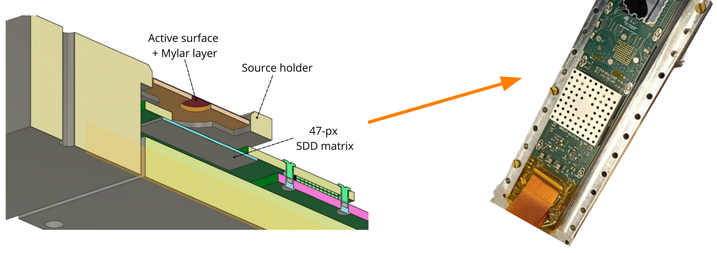


- shoot on target and measure backscattered electrons with SDD
- possibility to tilt egun and target
- test G4 simulations in reconstructing interactions with materials [5]

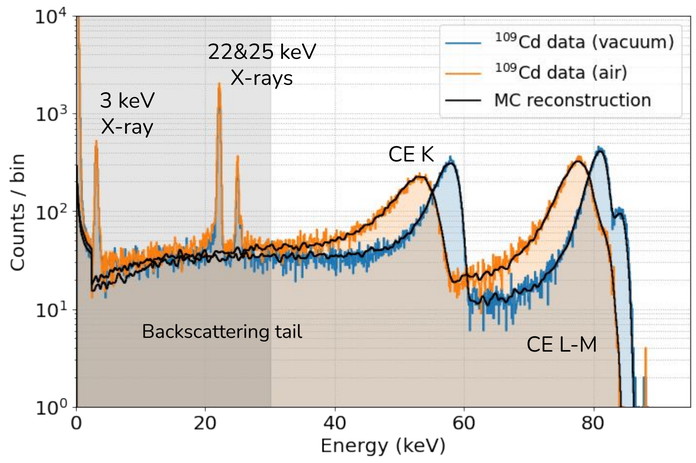


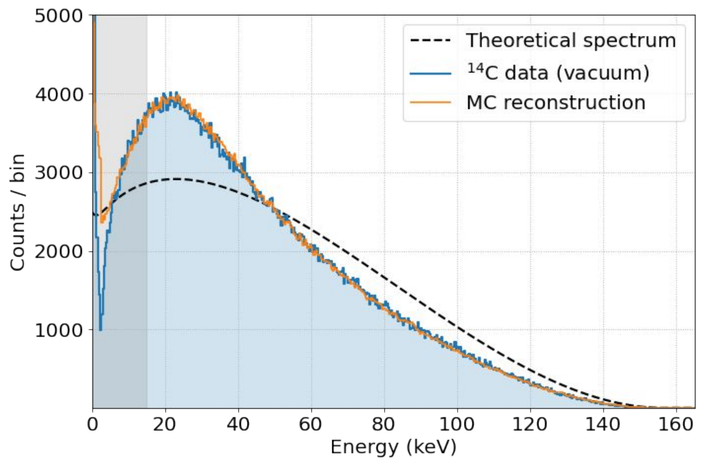
Next: **study different materials**

- **measurement of β spectra with SDDs** + reconstruction with G4
- first tests of SDDs at higher energies
- TRISTAN SDDs: 3mm diameter x 0.45mm thickness
- start with commercial sources:
  - **^{109}Cd**: monochromatic CE
  - **^{14}C**: allowed β spectrum (Q~156keV)
- auto-absorption in the source is important → fit for source thickness
- avoid border effects using multi-pixel cut



ASPECT-BET proof of principle

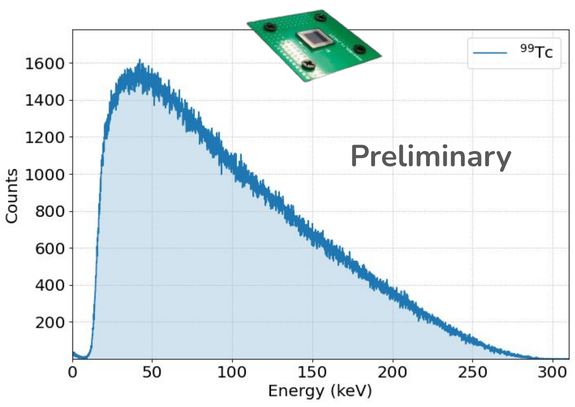




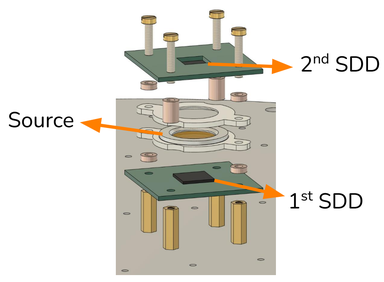
Excellent reconstruction of monochromatic and β spectra from commercial sources, indicating G4 capability to model electron interaction with light materials and SDD response

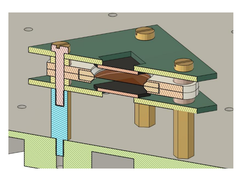
Towards forbidden β spectra measurements with SDDs

- Need to go to even higher energies for forbidden decays → new setup:
  - **thicker and larger SDD** to contain >500keV electrons and reduce border effects → 8mm side x 1mm thickness from FBK
  - extended dynamic range by custom amplification system
- Commissioning of new devices completed: first tests show promising results up to ~300keV: **^{99}Tc 2nd non-unique forbidden decay**



Next:
- fully characterize new SDDs
- fit different nuclear models to ^{99}Tc spectrum (and other forbidden spectra)
- develop technique to produce naked sources (less auto-absorption)
- sandwich configuration to reduce systematics (anti-coincidence measurement)





[1] S. Mertens et al. "*Sensitivity of next-generation tritium beta-decay experiments for keV-scale sterile neutrinos*". In: Journal of Cosmology and Astroparticle Physics (Feb. 2015)
[2] S. Mertens et al. "*A novel detector system for KATRIN to search for keV-scale sterile neutrinos*". In: Journal of Physics G: Nuclear and Particle Physics 46.6 (May 2019)
[3] M. Biassoni *et al.* "*ASPECT-BET: An sdd-SPECTrometer for BETa decay studies*". in: J. Phys.: Conf. Ser. (2023)
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[5] A. Nava *et al.* "*A Geant4-based model for the TRISTAN detector*". in: J. Phys.: Conf. Ser. (2021)

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For more details check our last preprint!