A TES for ALPS II

Rikhav Shah¹, Katharina-Sophie Isleis², Friederike Januschke², Axel Lindner², Manuel Meyer³, Gulden Othman, Matthias Schott², Christina Schwemmbauer², José Alejandro Rubiera Gimeno³

for the ALPS Collaboration

¹Johannes Gutenberg-Universität Mainz
²DESY Hamburg, now: Helmut-Schmidt-Universität, Hamburg
³Deutsches Elektronen-Synchrotron, DESY Hamburg

Axions, ALPs, and the TES

• Axions and axion-like-particles predicted to solve strong CP problem in QCD [1], and are viable candidates for cold dark matter [2].
• Detection of these particles uses the Primakoff-like Skive effect [3] with photon coupling.
• ALPs I uses this to produce axions and ALPs (from photons) and subsequently detect them (Fig. 1).
• [ALPS I Overview talk by Gulden Othman, Tuesday 1130]


Produced signals are single 1064 nm photons, expected at the low rate of ∼100 cps.

Can be realised using a Transition Edge Sensor (TES), a superconducting energy resolution, high efficiency, and of achieving requisite low background.

Need a detector capable of low energy (~1 eV) photon detection with high efficiency, and are viable candidates for cold dark matter [2].

The extrinsic backgrounds however, depend on the fiber coupling efficiency.

Extrinsic Background Pulse

• Performing for all fit parameters: Measured background rate 6.9 - 10^4 cps [5] over 20 days

Visible for use in ALPS II considering intrinsic backgrounds

• The TES used is a tungsten microchip operated around its T_c = 148 mK, where a single photon can heat it by ~100 μK and increase resistance by ~ 600 μΩ.

Corresponding change in current is picked up by SQUIDs (Superconducting Quantum Interference Devices), as a signal pulse (Fig. 5).

Setup housed in dilution refrigerator capable of stable long-term operation at ≤ 30 mK.

The biasing I-V curve, in Fig. 4, shows the possible working points, and the selected one where the pulse (Fig. 5) is acquired.

A TES for ALPS II

Fig. 5: Magnified view of the tungsten TES (25 μm x 25 μm) manufactured by NIST, USA.

TES Characterisation

• Acquired TES pulses can be fitted with a response function, as in Fig. 5.

• Yields characteristic fit parameters for pulse type, such as pulse height and rise time, the latter scales with the energy deposited in the TES.

• In-energy resolution ΔE/E ≤ 5% can be achieved (4)

• Depending on working point settings and choice of response function.

• Other analysis methods also used: PCA (Principal Component Analysis) [4], and machine learning techniques.

• [See poster: Machine and Deep learning for background rejection in the ALPS II TES Detector, by Manuel Meyer]

• Fit parameters used to compare signals to backgrounds and set up selection method(s), adapted as baseline approach.

Intrinsics

Events triggered in the TES with any of the TES detector parameters:

1. Electromagnetic interference
2. Cosmic rays

Backgrounds

Extrinsics

Events triggered in the TES with an optical fiber connected to it, but no laser input

Black-body radiation (and pile-ups)

The extrinsic backgrounds are shown in Fig. 9, which summarise the selection cuts.

Efficiency

• Have achieved rates of intrinsic backgrounds down to 6.9 • 10^4 cps, but depends on orientation of the detector module and can be irreducible.

• The extrinsic backgrounds however, depend on the fiber coupling efficiency.

• A measurement setup (adapted from [6], shown below) has to be optimised further with fiber connections, etc.

Fig. 1: The evolution of the dark rate over the 20 day period, for intrinsic backgrounds shown in Fig. 9, which summarise the selection cuts.

Outlook

• Testing planned for characterisation of full background profile

• Designing TES implementation in ALPS II and TES Lab at experiment site

• Simulations of TES pulses and backgrounds also underway

• Expansion of working group with different collaborations to

  Test new TESs and cryogenic single photon detectors

  Understand scope for use of TESs in dark matter detection

  Moving and re-characterising system at ALPS II site

  Aim for DA2 in 2024

References