Parametrisation of the Silicon-Detector Temperature

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1 Introduction

The Silicon Tracking Telescopes (STT) of ANKE compose lithium drifted silicon semiconductor (Si(Li)) with a thickness of up to 7 mm. The operation parameters of such a diode depends on the silicon temperature.
For example the drift velocity of electrons e^- and holes (temperature T, detector thickness s and voltage U) have been parametrized as [1]

$$v_{e^-} = 2.1 \cdot 10^9 \cdot T[K]^{-2.5} \cdot \frac{U[V]}{s[cm]}$$
$$v_{holes} = 2.3 \cdot 10^9 \cdot T[K]^{-2.7} \cdot \frac{U[V]}{s[cm]}$$

As the peaking time of the amplifier is in the order of $1\,\mu s$ and the trigger needs around $600\,ns$, the drift time should be less than $500\,ns$ to give a negligible contribution in the energy resolution. Moreover different velocities lead to variations of the drift time. The drift time differences from electrons and holes will be used to obtain the penetration depth of stopped particles. Temperature stability is necessary to get a 3-dimensional information of the place where the measured particle is stopped. As it is impossible to mount a temperature sensor directly onto the detector one needs to find an indirect way to deduce the temperature of the Si(Li).

2 Experimental Setup

The experimental setup should be such that it provides the possibility to measure temperatures of the Si(Li) detector, of the Si(Li) frame, of the cooling liquid, of the environment as well as the power consumption of the silicon. This has

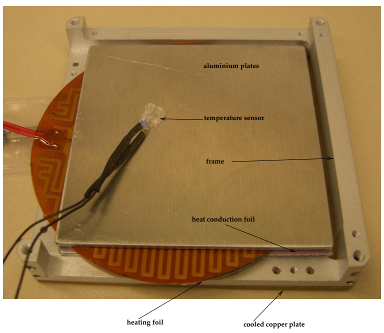

Fig. 1: Photograph of the main part of the experimental setup

been achieved by using an existing frame for the Si(Li) as the central part of the setup (See figure 1). The Si(Li) has been replaced by two aluminium plates (2 mm thick) with the area of the Si(Li). To simulate the power consumption P_{al} of the Si(Li), the plates have been equipped with a heating foil in-between. For good thermal conductivity additional heat conduction foils [2] have been used.
On the back side of the frame an actively cooled copper plate has been mounted. Here heat conducting foils have been used, too.
The setup was equipped with four temperature sensors:

- one $20\,mm \times 20\,mm$ thin sensor on the outer side of the aluminium: T_{al}
- one $2\,mm \times 10\,mm$ sensor on the frame: T_{fr}
- one $20\,mm \times 20\,mm$ thin sensor on the cooled copper plate: T_{liquid}
- one free hanging SMD-sensor to measure the temperature of the environment: T_{env}

This setup has been mounted on a DN 150CF-flange and put into vacuum. By externally heating up the vaccum test stand, the environment temperature could be increased.
The temperatures and the heating power have been taken after obtaining thermal equilibrium.

3 Results

In the first step an independent linear fit for the liquid and environment temperature and the heating power has been done. With respect to the correlations between the parameters small corrections of the fitted coefficients have been established.
The formular for the aluminium temperature is:

$$\mathrm{T_{al}} = 0.8 \cdot \mathrm{T_{liquid}} + 0.2 \cdot \mathrm{T_{env}} + 2.0\,\frac{\mathrm{K}}{\mathrm{W}} \cdot \mathrm{P_{al}}$$

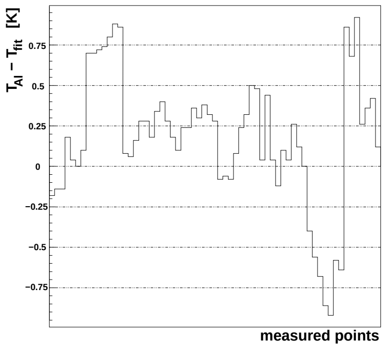

Fig. 2: Difference between the temperature of the aluminium and the fitted temperature.

Since the power consumption of the silicon will be less than 100 mW the third term can be neglected and the final formula is:

$$\mathrm{T_{al}} = 0.8 \cdot \mathrm{T_{liquid}} + 0.2 \cdot \mathrm{T_{env}}$$

Fig.2 shows that the discrepancy is less than ± 1 K and that it is possible to operate the silicon detector at any chosen temperature with a precision of better than ± 1 K. This corresponds to a systematic error in the drift time of less than ± 20 ns.

References:

[1] G. W. Ludwig and R .L. Watters, Phys. Rev **101** (1956) 1699.
[2] *http://www.alfatec.de/www_alfatec/kerafol_14_14_0_f.htm Keratherm_deu_08_2005.pdf*

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