Absolute Energy Calibration of Micron Detectors for the ANKE Silicon Tracking Telescopes.

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The ANKE Silicon Tracking Telescopes (STT) are designed to measure the total energy of a stopped particle with a precision of about 1 %. A calibration method, which has been applied up to now [1], is using a test-pulse and additional adjustments by fitting real data to the expected values, in particular dE/E plots. Due to the absence of an absolute energy reference, the achieved accuracy was of the order of 6%. The method described in this article provides a calibration point, detecting radiation an from α-source.

At this level of precision not only the calibration of energy losses in the sensitive detector zones (E_{meas}) have to be done carefully, but also losses in dead layers (E_{dead}) have to be taken into account. Information from Micron Semiconductor (UK) asserts a dead layer thickness on each detector side of about 4-5μm, which varies by about 1μm across the detector as shown in Fig. 1. An exact measurement of the dead layer thickness is necessary to provide the E_{dead} reconstruction. Due to the fact, that the dead layer has a two-step structure, two independent measurements are needed, which was achieved by a combination of two α-sources.

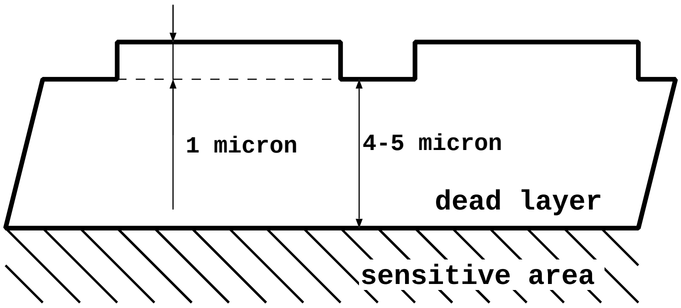

Fig. 1: Principle dead-layer structure on the surface of the detectors.

Measurements under vacuum with an ^{241}Am α-source were made in April 2005. Figure 2 presents a typical spectrum of the detected energy. The two-step structure of the dead layer results to a clear splitting of the α-peak. An estimation of a difference between the peak mean values is 160 keV and of peak standard deviations σ are 50 keV, assuming the dead layer of 5μm.

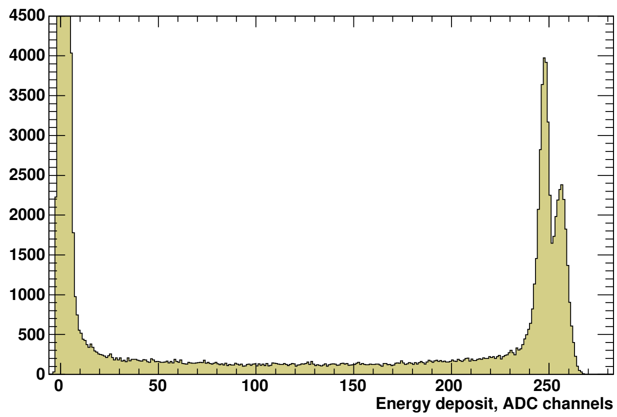

Fig. 2: Energy deposit of particles from ^{241}Am is presented in arbitrary units.

As shown in [2], E_{meas} can be described as $k \cdot f(N_{ADC})$, where $f(N_{ADC})$ is a read-out responce function, defined by the test-pulse calibration, and k is a calibration factor, introduced by the difference between the effectively used test pulse capacitance and the nominal capacitance. A dead layer energy loss can be calculated from the initial particle energy E and the dead layer thickness d. So, it can be expressed as $F(E,d)$. In vacuum E is equal to the sum of E_{meas} and E_{dead}:

$$E = k \cdot f(N_{ADC}) + F(E,d), \tag{1}$$

Due to the two-step structure, two values for the thickness d_1 and d_2, are required, and three values (k, d_1, d_2) are to be determined.

A combination of ^{239}Pu (E_α = 5.156 MeV) and ^{244}Cm (E_α = 5.805 MeV) can be applied to obtain a set of four peak with a good resolution. A non-linear system of equations can be created, and a numerical method was developed to solve this system and calculate d_1, d_2 and k with an error, much smaller than 1%. In a general way $F(E,d)$, expressed as an integral over the Bethe-Bloch formula [3] is very complicated, so it was approximated taking into account the confines on the dead layer thickness and fitting SRIM data [4]. The numerical method applies an iteration process of analytical solutions for the system, linearized in each iteration by linear interpolations of $F(E,d)$.

Knowing the dead layer thickness and measuring E_{meas}, the approximated $F(E,d)$ function can be used in experiments to reconstruct E_{dead} for particles of different types. In experiments, a proton with a primary energy of 8 MeV will pass through all four dead layers of the detectors and total loss E_{dead} there will be about 3 % of the original energy. The energy straggling in the dead layers will be negligibly small.

Thus, the absolute values of the energy loss in sensitive zones of the STT detectors will be measured and the losses in the dead layers will be reconstructed with high precision. An installation of α-sources near the STT at ANKE will provide monitoring of the energy measurement stability during the time of experiments.

References:

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