Progress in STT energy calibration

G. Macharashvili and M. Zhabitsky for the PAX collaboration

The ANKE Silicon Tracking Telescopes (STTs) serve to reconstruct charged particle tracks in a region close to the interaction point. There are two identical telescopes located in the beam pipe to the left and to the right with respect to the beam–target crossing point parallel to the proton beam. Each telescope contains three double sided strip silicon layers of thickness 69 μm, 300 μm and 5.1 mm. Thin layer is as close as 28 mm to the beam line.

In 2011 STTs were used to measure polarization of a stored beam during the spin-filtering experiment. To define STTs parameters, used to convert detected electronic signals into valuable physical quantities, several corrections procedures are employed: pedestals finding, thresholds setting, an absolute calibration. Meanwhile for energy measurements only N-side vs P-side relative calibration was used, which implies the homogeneous response from all segments on each side of a layer. In 2012 we have derived a procedure to define a relative N-side vs P-side correction in a segment-wise way.

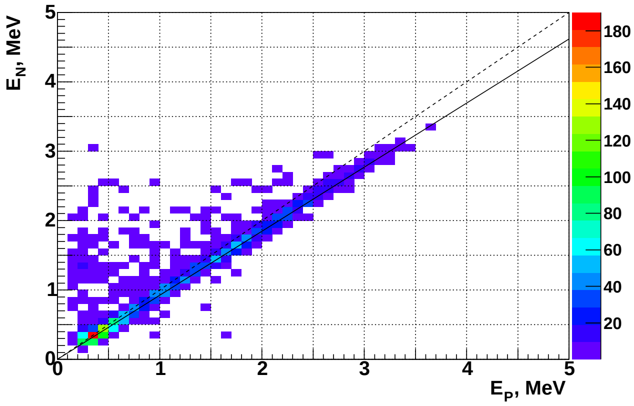

Fig. 1: Typical E_N–E_P correlation plot for a segment from P-side of the thin plane with respect to all N-segments connected to a reference chip. Dash line corresponds to $E_N = E_P$, solid line — fit result.

As a particle crosses a silicon layer, free electrons and holes produced by ionization are collected on corresponding sides. The proposed procedure requires both reconstructed energy deposits to be equal within an expected signal uncertainty. The task is fulfilled by means of introduction of free multipliers k_{N_i} and k_{P_j} which will transform reconstructed energy deposits E_{N_i} and E_{P_j} into aligned values $E'_{N_i} = k_{N_i} E_{N_i}$ and $E'_{P_j} = k_{P_j} E_{P_j}$. Values of k_{N_i} and k_{P_j} are obtained through the minimization of a sum of weighted distances from registered (E_{N_i}, E_{P_j}) pairs to the $E'_{N_i} = E'_{P_j}$ line (see Fig. 1). Special measures are used to suppress 'off-diagonal' events, which arise either from incomplete charge collection by either side or incoherent signals combinations.

Due to large number of N- vs P-segments combinations, to effectively exploit available statistics, the segment-wise relative calibration should involve all k_{N_i}, k_{P_j} multipliers in a common overall minimization. In turn this minimization problem is difficult to solve as a number of degrees of freedom exceeds one hundred.

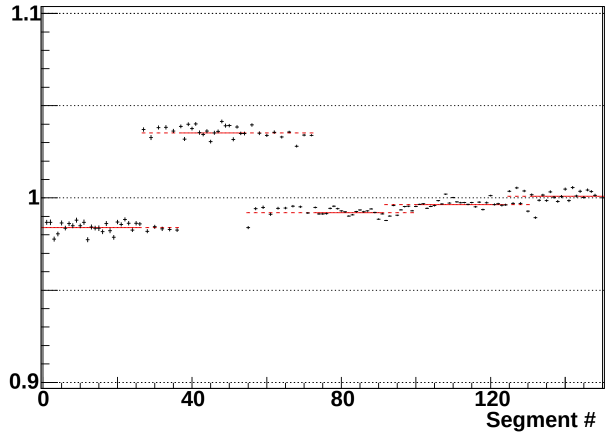

Fig. 2: The typical correction factors for the 300 μm thick layer: segment-wise (black) and chip-wise (red).

It was observed that values of corrective multipliers are correlated for segments connected to the same electronic chip. Therefore, number of multipliers can be reduced to the number of connected chips minus one due to relative nature of the correction. In this chip-wise approach the number of degrees of freedom in the minimization problem is of order of ten, its numerical solution is illustrated in Fig. 2. Then multipliers are refined by sequentially perturbing a single coefficient $k_{N,i}$ while other coefficients are fixed.

The profit from the introduced N vs P segment-wise alignment can be illustrated on the sample of exclusive elastic $pd \to pd$ scattering events at $T_p = 49.3$ MeV: resolution in reconstructed $E_{\rm tot}$ has been improved from 0.39 MeV to 0.28 MeV (Fig. 3).

Further improvement in resolution is expected by means of test-pulse calibration, which will ensure linearity of the detected signals to the energy deposited in a silicon layer.

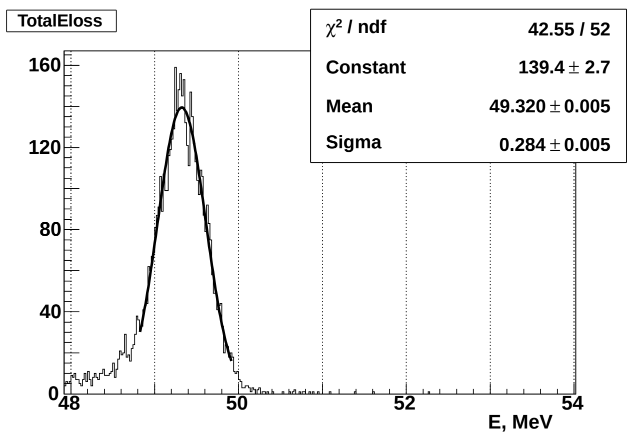

Fig. 3: Reconstructed $E_{\rm tot}$ for elastic $pd \to pd$ with proton and deuteron detected with the telescopes.