Timing Performance of the ANKE Silicon Tracking Telescopes.

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An important application of the ANKE Silicon Tracking Telescopes (STT) will be a time-of-flight particle identification. Reactions of type $pd \to p_s pX$ or $pd \to p_s dX$ are investigated in ANKE, detecting a fast proton or a deuteron in FD ANKE and a spectator proton p_s in STT ANKE. The time resolution (FWHM) of FD is about 600 ps. If the STT will have a similar accuracy, the reactions can be clearly identified, measuring their time difference, because even fast (3 GeV/c) deuterons, detected in FD, have a time-of-flight at least 3 ns larger than the fast protons. Two experimental setups were realized in laboratory in order to directly measure the STT timing accuracy.

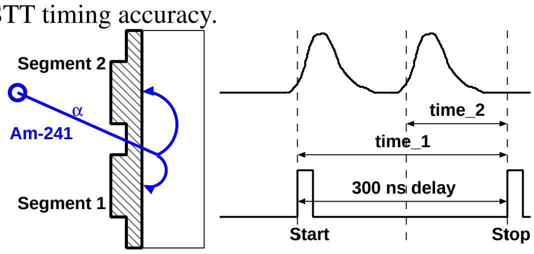

Fig. 1: Experimental setup and simplified time diagram of measurements with the α-source.

The first setup allows to study the dependence of a time walk and the standard deviation on the deposited energy in the sensitive detector zone from 400 keV up to 2 MeV, typical for spectator protons. Front-end electronics, based on the MATE3 chip [1], provides simultaneous time and energy measurement. The measurement uses an ^{241}Am α-source in air, in order to provide an energy variation of α-particles from the mono-energetic source. Particles, detected in the same segment, have different path length in air and consequently different energies, when they impinge on the detector. The experimental scheme is presented in Fig.1. α-particles, which impinge between two adjacent segments, were detected, and the difference between two measured times was studied. Due to the fact, that the desired accuracy is close to the limits of the read-out electronics performance, a dedicated procedure of handling of time peaks and a compensation for the ADC differential non-linearity were applied.

A standard deviation of the time difference $\sigma_{\Delta t}$ can be expressed as:

$$\sigma_{\Delta t}(E_{st}, E_{sm}) = \sqrt{\sigma^2_{st}(E_{st}) + \sigma^2_{sm}(E_{sm})}, \qquad (1)$$

where σ_{st} is the resolution of a segment ST, produced the trigger, and σ_{sm} is the resolution of a measured segment (SM).

The dependence $\sigma_{sm}(E_{sm})$ for one segment alone was extracted from Eq.1 and described as:

$$\sigma_{sm}(E_{sm}) = \sigma_0 + exp(p_1 + p_2 \cdot E_{sm}), \qquad (2)$$

where p_1 and p_2 are fit parameters. σ_0 is the standard deviation of the used electronics. The dependence of $\sigma_{sm}(E_{sm})$ is presented in Fig.2 and data points for two arbitrary chosen ranges of E_{st} are also shown in order to illustrate the independence of the obtained σ_{sm} on E_{st}, the energy in a different segment .

A similar procedure was made to obtain the time walk of the SM, the dependence of the time peak position T_{sm} on the deposit E_{sm}. This dependence is depicted in Fig.3, it was expressed as:

$$T_{sm}(E_{sm}) = p_0 + exp(p_1 + p_2 \cdot E_{sm}), \qquad (3)$$

Data points for different E_{st} values show some systematic deviations from the function, fitting all events. It indicates that the description of the $T_{sm}(E_{sm})$, provided by the investigation method, is not completely independent on the responses of other segments. The deviations are significant (about 1 ns) only near the MATE3 threshold (0.4 MeV), so may be the behavior of the electronics introduces this uncertainty in that region.

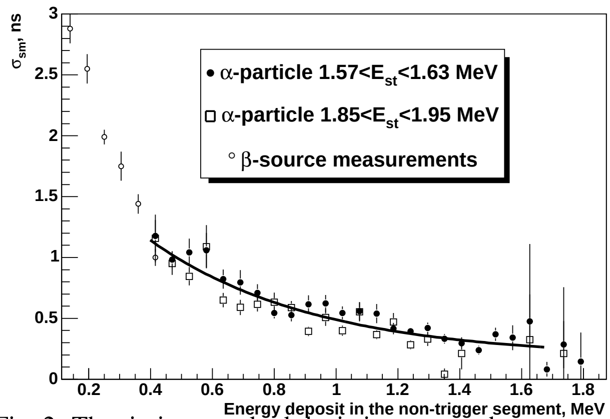

Fig. 2: The timing standard deviation versus the energy deposit. The dependence for the α-measurements is shown by a solid line.

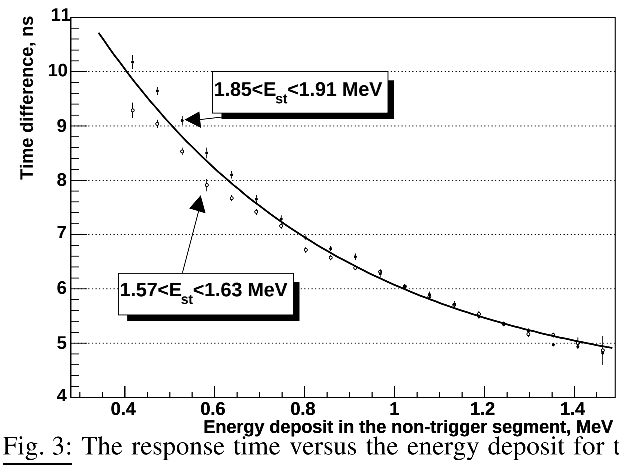

Fig. 3: The response time versus the energy deposit for the measurements with the α-source.

An inverse negative relationship of the deviation value and sum energy deposit ($E_{st} + E_{sm}$) was found, so another possible explanation is, that this systematical deviation results from a skin-deep penetration of α-particles in a detector sensitive region. Actually, α-particles with an energy deposit of 500 keV have a penetration depth of less than 1 μm, taking into account its inclination in the measurements. The internal electric field of the detector may be affected at that depth by surface effects, that influences the drift time. A planned measurement with a proton beam of the Cologne Tandem-Accelerator will provide a wide range of the penetration depths and will test this hypothethis.

Measurements with a β-source are also free of the surface effects. The second setup was developed in order to study the timing for electrons. Since the electron energy losses are rather small, these data can be used only as a reference. It was estimated, using Ref.[2] data, that the proposed setup provides data for the deposited energy up to 500 keV. Electrons from a ^{90}Sr source were detected by two scintillator counters and the investigated silicon detector (Fig.4). A scintillator signal coincidence was used as reference time and as trigger for the silicon detector read-out. The scintillator time resolution (FWHM) was measured to be 600 ps.

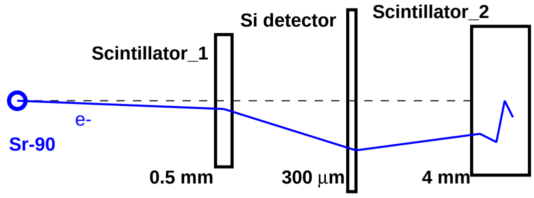

Fig. 4: Experimental setup for the β-source measurements.

The dependence of the time walk on the energy deposit in the range 0.14 MeV$\leq E_{sm} \leq$0.4 MeV was described in the form of Eq.3 and the resolution dependence as in Eq.2. The results forσ_{sm} of both methods are in agreement in the overlap region (see Fig.2).

Thus, the performed measurements allow to estimate the time resolution (FWHM) to better than 1 ns for an energy deposit above 1 MeV. The dependence of the time walk on the energy deposit is also obtained with the suitable uncertainty. The accuracy of the STT timing, obtained in the laboratory measurements, is high enough for the time-of-flight particle identification. The timing for protons will be tested at the Cologne Tandem-Accelerator during 2006.

References:

[1] P.Baron *et al*. MATE, a single front-end ASIC for silicon strip, Si(Li) and CsI detectors. *Nuclear Science Symposium Conference Record*, v.1, p.386-390. IEEE, October 2003.

[2] Casino - Monte Carlo Simulation of Electron Trajectory in Solids, Version 2.0, http://www.gel.usherbrooke.ca/casino/index.html

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