



Particle Identification Using the Time-Over-Threshold Measurements in Straw Tube Detectors

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Abstract

Identification of charged particles based on energy losses in straw tube detectors has been simulated. Response of new front-end chip developed for the PANDA straw tube tracker was implemented in the simulations and corrections for track distance to sense wire were included. Separation power for p - K , p - π and K - π pairs obtained using the time-over-threshold technique was compared with one based on measurement of charge.

PANDA Straw Tube Tracker

In the PANDA experiment, the Straw Tube Tracker (Fig. 1) designed for momentum analysis of charged particles in a 2 T magnetic field will be also used for separation of protons, charged pions and kaons in the momentum range below 1 GeV/c. The tracker consists of 150 cm long straw tube detectors arranged in 27 layers in a cylindrical volume around beam axis.

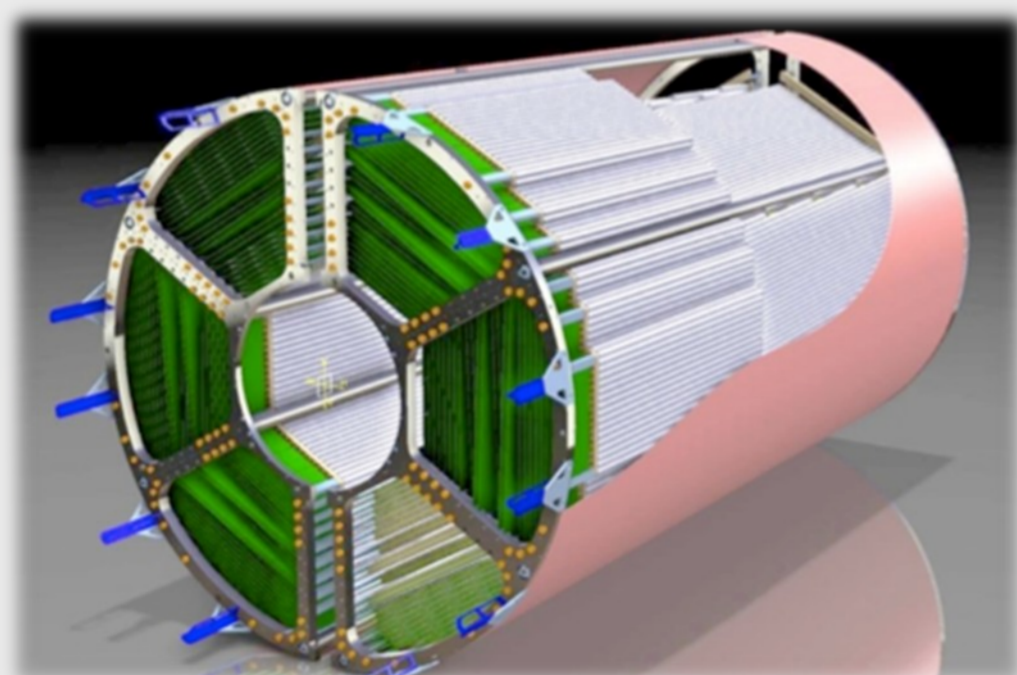


Figure 1. General layout of the Straw Tube Tracker.

The straw tubes are made of a 27 μm thick aluminized Mylar foil and have a diameter of 10 mm. A gold plated tungsten wire with 20 μm diameter is used as an anode (Fig. 2). The gas overpressure of 1 bar makes the straws self-supporting.

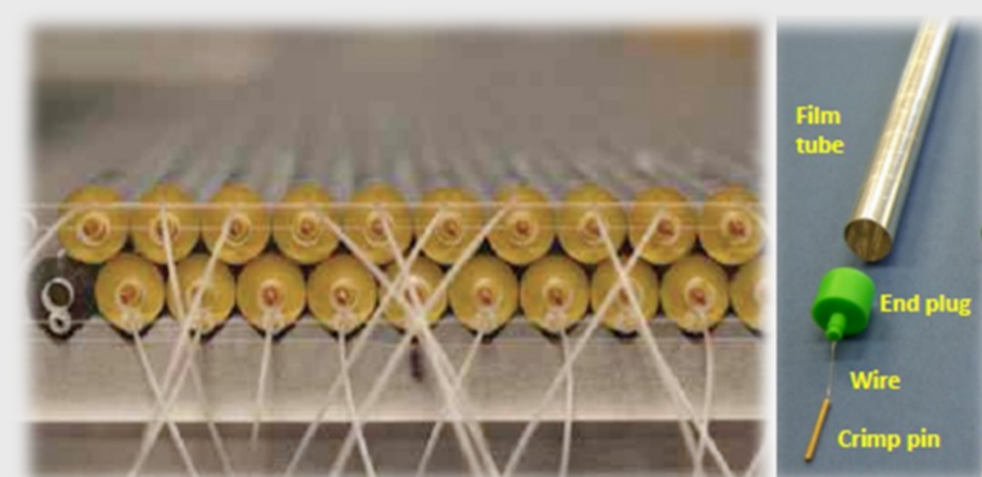


Figure 2. Double layer of straw tubes (left) and straw tube with end-plug (right).

For registration of the energy losses in the straw two options were considered: (i) measurement of the Time-over-Threshold (TOT) (ii) digitization of pulses in sampling ADC and determination of charge (Q). An advantage of the TOT method is that the read out electronics can be restricted to time measurements.

For reading out the straw tube signals in the PANDA experiment, a new front-end chip is being developed. It comprises a charge preamplifier stage, a shaper stage with a pole-zero cancellation, a tail cancellation network and a baseline holder for each channel. Besides, a leading edge discriminator circuit with a fast LVDS output and an analog output buffer provide both, the timing and the amplitude information (Fig. 3). The first prototype chip was fabricated in the AMS 0.35 μm technology.

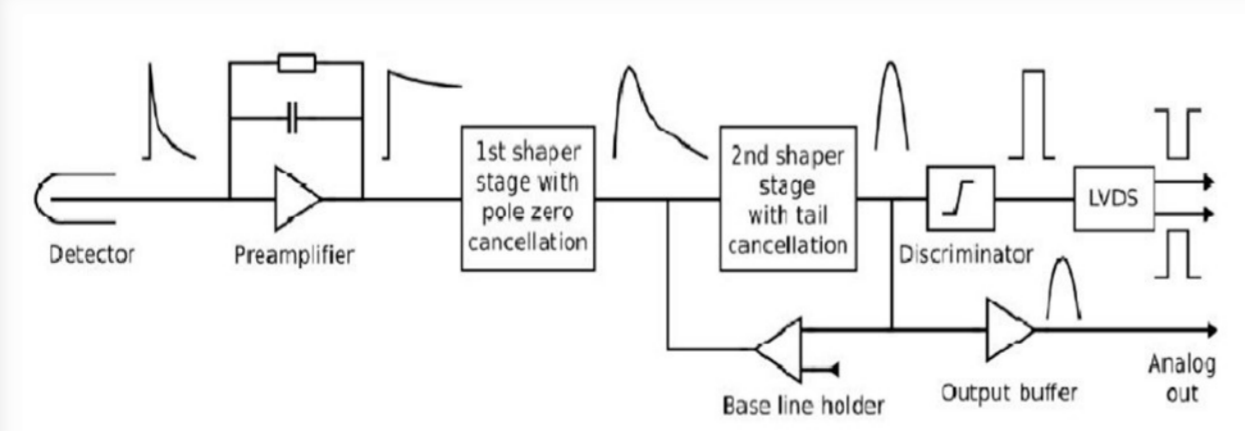


Figure 3. Block diagram of straw tube front-end.

Some parameters of the front-end chip are programmable. In order to optimize the tail cancellation, the time constants were adjusted using signals from the straw irradiated with ^{55}Fe X-ray source. Test performed with 2.7 GeV/c proton beam, with a rate exceeding 1MHz has showed that there was no baseline distortion with the chosen parameters.

Simulations of Straw Response

The particle identification based on energy losses in the straw tubes was studied using simulation of the straw tube pulses with the Garfield-9 program. The properties of the 90%Ar+10%CO₂ gas mixture, which was chosen for the straw tube tracker, were calculated with the Magboltz code, version 8.9.5. The straw tube pulses were convoluted with a transfer function of the front-end electronics, which was determined as a response to a "delta-like" pulse injected into the front-end channel. Results of the simulations have been examined by a comparison with tests performed with ^{55}Fe . The Fig. 4 shows a good agreement between time-over-threshold spectrum simulated and measured for ^{55}Fe .

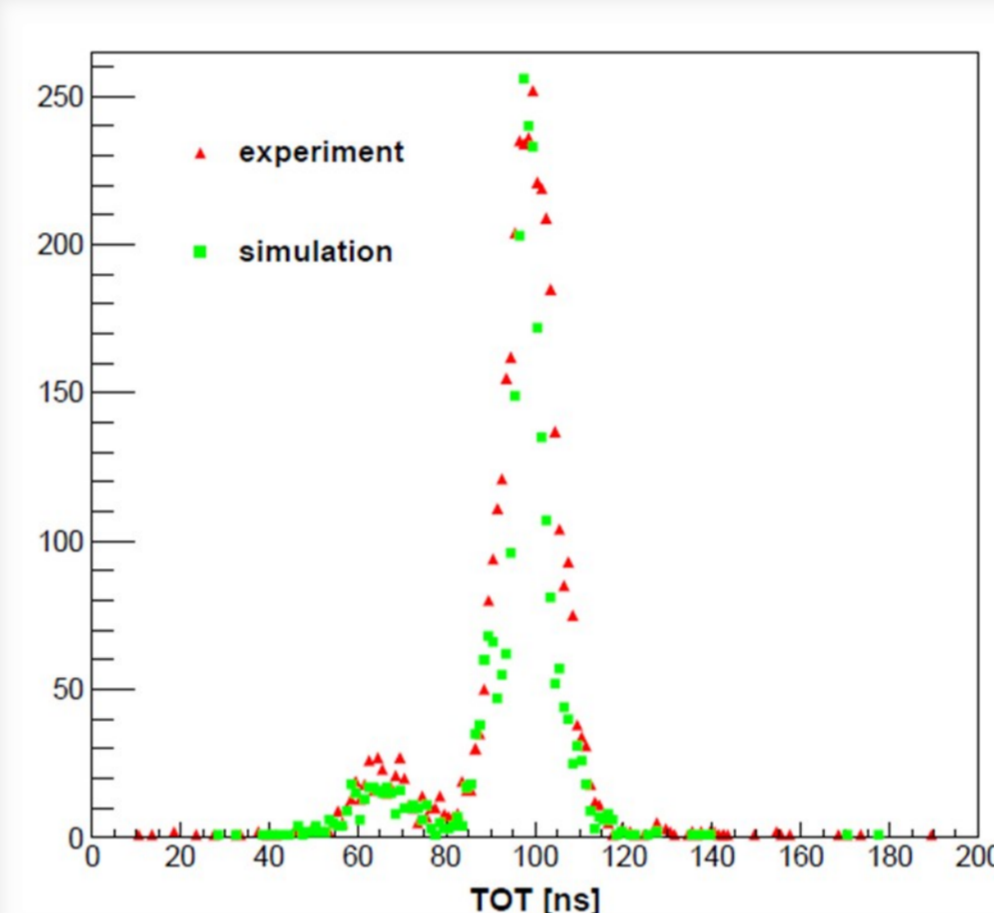


Figure 4. TOT spectrum measured and simulated for ^{55}Fe source. Peak corresponding to full absorption of 5.9 keV X-rays from ^{55}Fe is clearly separated from 2.9 keV argon escape peak. The discrimination threshold was set to 20 primary electrons.

The simulated TOT vs. input charge was also compared with test results with ^{55}Fe for different HV from 1600-2000V (see Fig. 5). For high input charges, the measured TOT deviates from simulations due to saturation of pulses in the shaper.

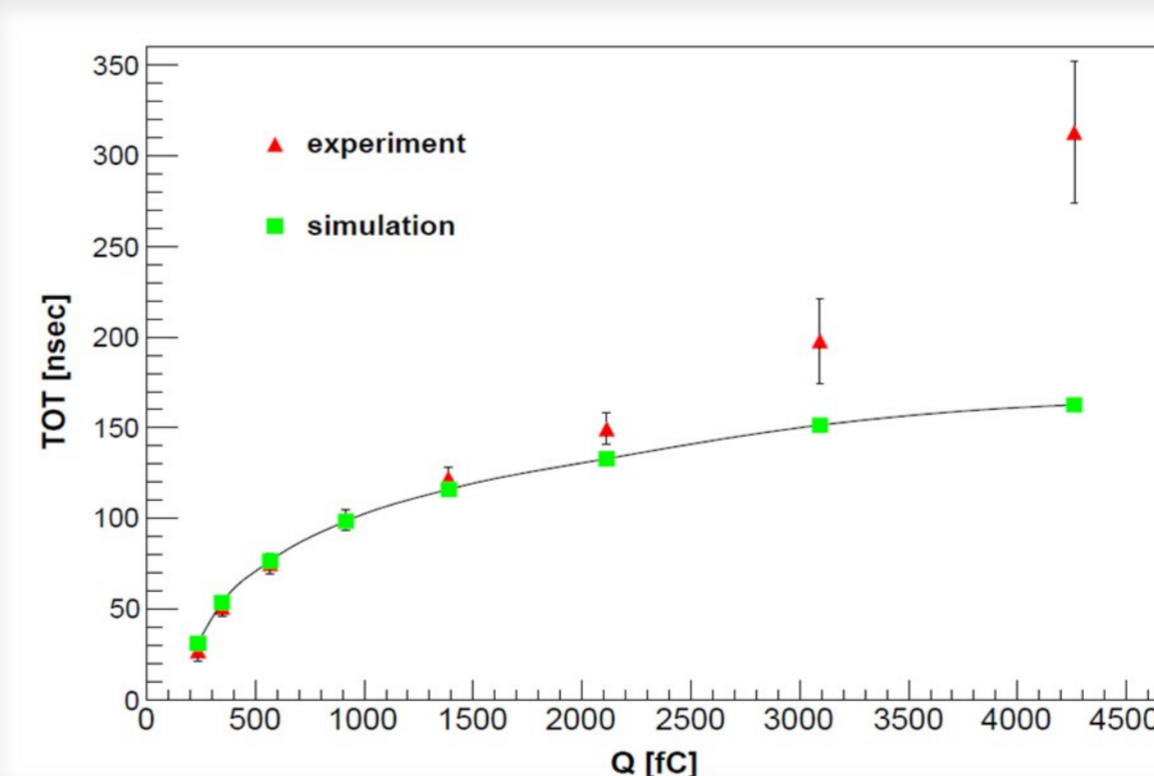


Figure 5. TOT vs. input charge for ^{55}Fe .

The TOT depends on the particle's energy loss and can be used for particle identification. However, it also depends on the track position inside the straw. In order to extract information about the energy loss of a particle, TOT was corrected for this dependence. Fig. 6 shows the correction for 0.7 GeV/c kaon.

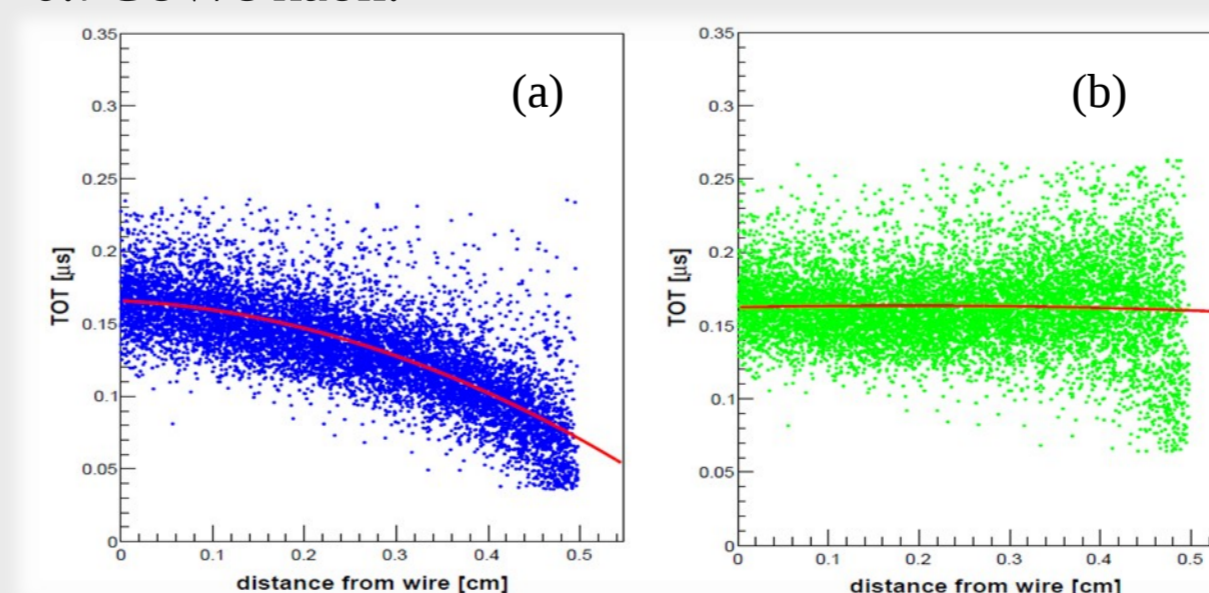


Figure 6. Simulated TOT (a) before, (b) after distance correction for 0.7 GeV/c kaon.

π - K - p Separation

Simulations of the particle identification in the straw tubes were performed using pseudo-tracks passing through 24 straw tube layers. Simulations were done for sense wire potential of +1800V corresponding to the gas gain of 4.4×10^4 and the discrimination threshold for the TOT measurement equivalent to 20 primary electrons. Subsequently, a truncated mean was calculated for each track by discarding 30% of the largest values. The values of truncated average were then used for calculating the separation power for p - π , p - K and π - K which is shown in Fig. 7 as a function of particle momentum.

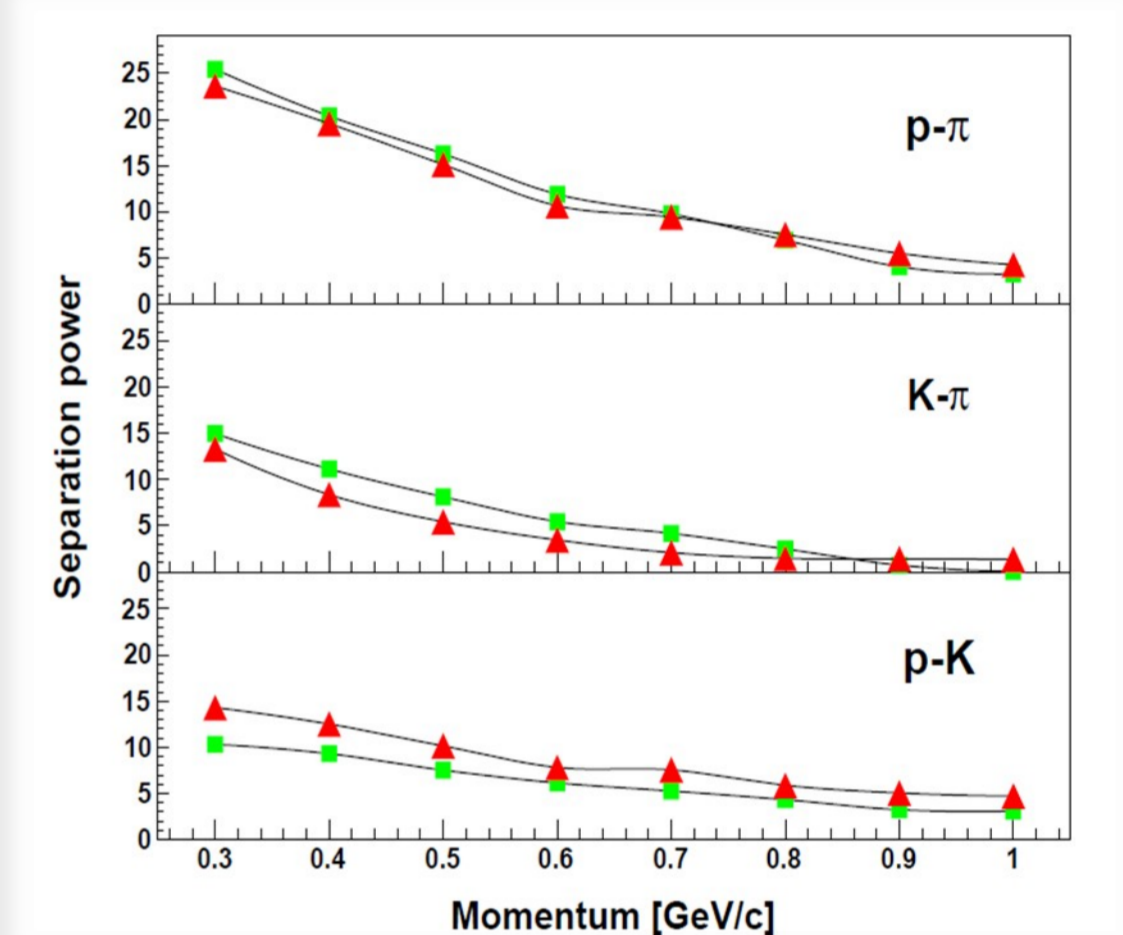


Figure 7. Separation power for p - π , p - K and π - K pairs based on TOT (\blacksquare) and charge (\blacktriangle) measurement.

The p - π separation based on TOT and Q are similar. In the case of K - π and p - K pairs, the separation power calculated using TOT and Q are differ due to saturation of TOT as a function of Q for high energy deposits in the straws with Fig. 8.

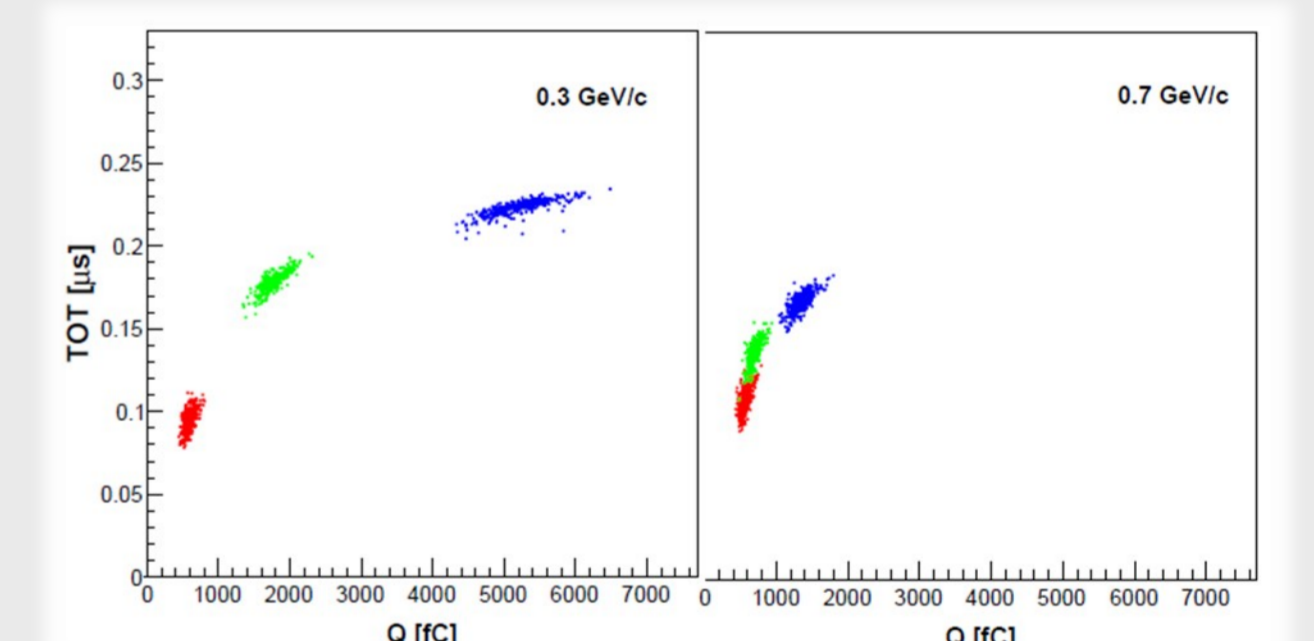


Figure 8. TOT vs. Q for protons (\star), kaons (\bullet) and pions (\circ) with momentum 0.3 and 0.7 GeV/c.

Saturation leads to smaller relative smearing and lower difference of the corresponding mean values of TOT than Q.

We conclude that the separation power based on the TOT and Q measurements are comparable in the investigated momentum range 0.3-1.0 GeV/c.

References

1. S. Constanza, Tracking with straw tubes in the PANDA experiment, 13th ICATPP Conference on Astroparticle, Particle, Space Physics and Detector for Physics Applications, 3-7 Oct. 2011, Como, Italy.
2. T. Akeson, et al., Particle identification using the time-over-threshold method in the ATLAS Transition Radiation Tracker, NIM A474(2001), 172-187.

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