PROCEEDINGS OF SCIENCE

Application of straw detector for particle identification - feasibility studies with PANDA STT prototype

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In the PANDA experiment at the HESR antiproton storage ring of the FAIR facility in Darmstadt (Germany) the central tracker is a key element which will provide information about decay vertices, momenta and the type of charged particle emitted in antiproton annihilation. Various techniques are known for the extraction of energy-loss information from analog signals of gaseous detectors like straw chambers. These include electronical techniques as well as off-line treatment of the data. The main difficulty lies in the poor statistics of the formation of electron-ion clusters and in the strong asymmetry of the Landau distribution. A general-purpose chain of electronics and data acquisition based on sampling ADCs has been developed which permits off-line application of various techniques.

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1. Introduction

The PANDA experiment will use high intensity cooled antiproton beams provided by the HESR storage ring. Various fundamental issues of hadron and nuclear physics can be investigated by the PANDA experiment. Studies of charmonium and open charm physics, gluonic excitations, CP violation, nuclear structure, hypernucleus physics and many other aspects of interaction of antiproton with nucleons and nuclei are planned [1]. For such broad spectrum of forseen investigation very good tracking and particle identification is needed. The tracking system of the target spectrometer consist of the Micro Vertex Detector (MVD) and Central Tracker (CT). Two options for the central tracker are under discussion: The Straw Tube Tracker (STT) and the Time Projection Chamber (TPC). In this article the ongoing studies on particle identification based on the measurement of energy loss will be presented.

2. The PANDA Straw Tube Tracker (STT)

The Straw Tube Tracker fills a cylindrical volume with a length of ca. 150 cm, an outer diameter of 42 cm and an inner diameter of 15 cm in the center of the PANDA detector [2]. The straws are made of two layers of 12 μm mylar films glued together to 1 cm diameter tubes, the anode is made from a gold–plated tungsten–rhenium wire with 20 μm diameter. They will be operated with an ArCO2 mixture (90/10 % or 80/20 %) at 1–2 bar overpressure and a high voltage of 1750–1850 V. The individual straws are packed in double layer glued together with a precision of 50 μm. These double layers are arranged in six hexagonal sectors see Fig. 1. Four skewed double layers with an angle of +/- 3 degree with respect to the beam axis are forseen. The construction is self supporting and therefore has a small material budget. A straw tracker with the same construction principle is successfully used by the TOF detector at COSY Juelich [3]. A total number of ca. 4600 straws will be used, the number of layers will be from 21 to 27. The large number of straw layers gives the possibility to use STT also for dE/dx based particle identification by determining the energy loss [4].

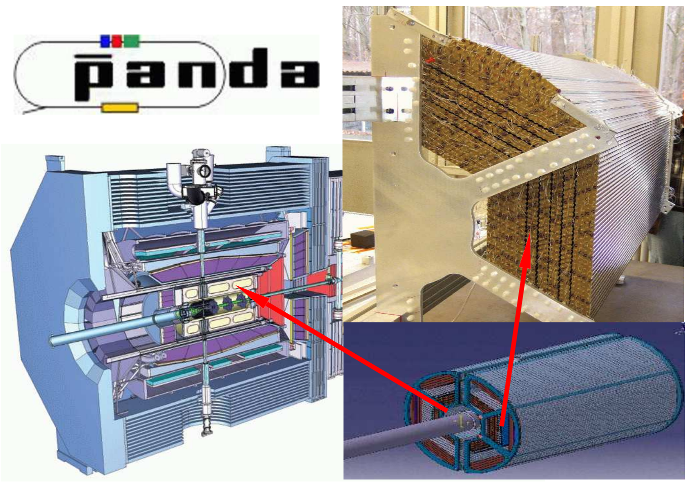

Figure 1: The Straw Tube Tracker as central tracker detector for the PANDA experiment.

3. The experimental setup for energy-loss measurements

The most stringent limitation of the energy-loss resolution of gaseous detectors comes from the rather low energy loss in gases leading to poor statistics of the number of electron clusters. This aspect is illustrated in Fig.2; the region of interest for our studies below 1 GeV/c. For 1 cm diameter straw tubes as planned for the PANDA STT sufficient energy-loss resolution for a given particle track can only be expected when the energy loss is simultaneously measured by many straw tubes. Therefore in our investigations a set of 128 straw tubes was used consisting of 8 planar layers with 16 tubes each.

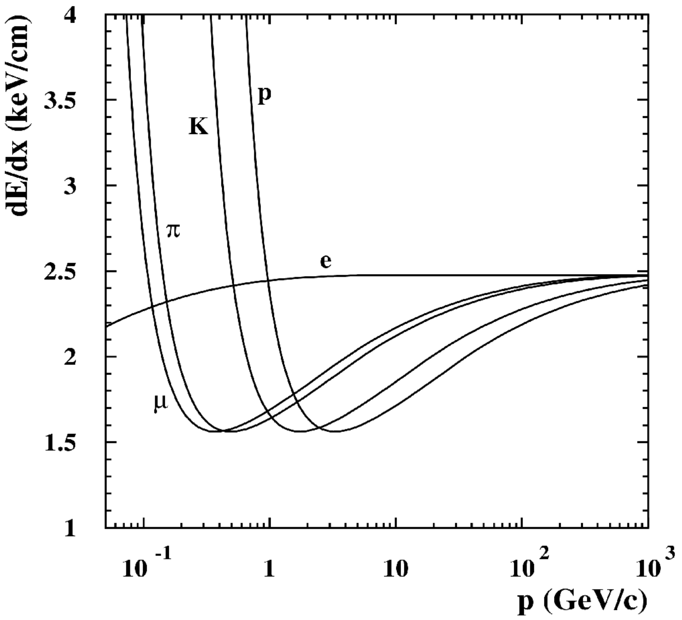

Figure 2: The specific energy loss for various kinds of particles.

The straw chambers of the PANDA type where placed in a monoenergetic proton beam of COSY-Juelich [6] using an external beam line, see Fig. 3. In addition to the straws, planar drift chambers were placed in upstream and downstream direction. The trigger signal was derived from scintillators.

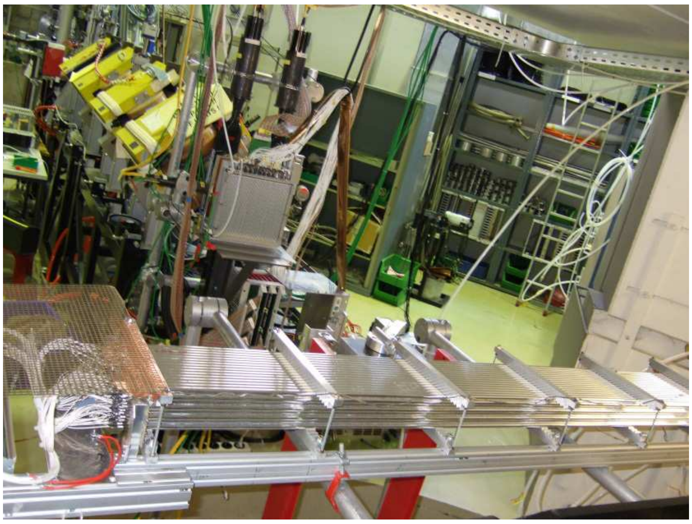

Figure 3: The straw tube tracker (foreground), drift chamber and beam-line quadruples (yellow).

Analog signals from the straw tubes where fed via 50 cm long coax cables into fast current amplifiers and subsequently analyzed by 240 MHz sampling ADCs developed for this application at FZJ and Uppsala University. 8 modules with 16 channels each were used. They feature 12 bit resolution and include an FPGA for various kinds of pulse analysis. For the present investigations data were usually recorded in the raw mode in order to have full freedom for the off-line application of any type of analysis.

The sampling ADC [5] was develop for the WASA at COSY experiment [7].

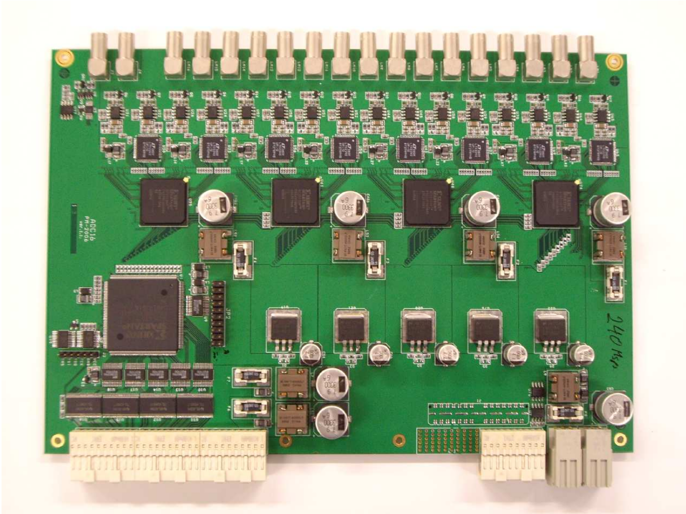

Figure 4: The 240 MHz 12–bit sampling ADC. The 16 signals inputs, test pulse input and trigger input are on the front side while LVDS bus connectors are on the rear side.

4. Techniques for the raw signal analysis

The possibility to collect raw signals with sampling ADCs gives us the possibility to simulate off-line various kinds of electronical hardware like different types of shaping amplifiers, discriminators and pulse-analyzing devices.

4.1 Extraction of energy loss information

Signal integration inside fixed gate is a standard method used in QDCs; the principle is presented in Fig. 5. It is easily implemented, the results strongly depend on the selected position and length of the integration gate and they are sensitive to changes in baseline, thus they can be rate depended. The use of full signal shape information give the possibility to define the parameters of the integration for each signal individually. The baseline level can be determined before the signal, start the integration as a signal started and stopped precisely at the beginning or the end of the signal. Furthermore, pile-up rejection for individual signals can be performed.

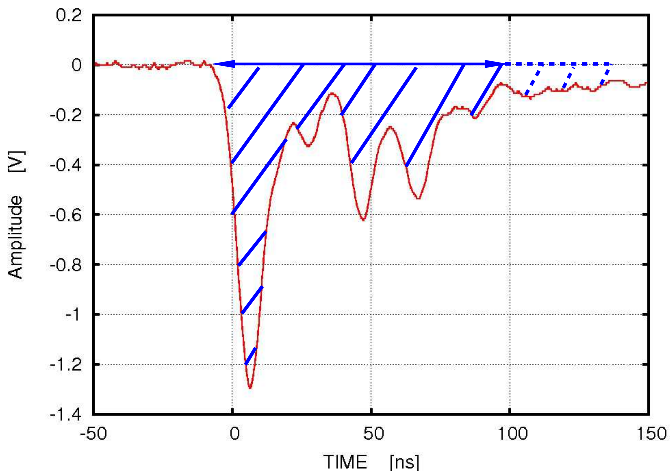

Figure 5: Charge integration in selected window.

Other method to get the energy loss information is to determine the time the signal was over the selected threshold (Time over Threshold–ToT) [8]. The assumption in this method is that larger energy losses give larger, broader signal and stays longer over selected threshold (Fig. 6). Such method is easy to implement but as can be seen from Fig. 6 the result strongly depend of selected threshold it is also not clear what to do with signals with several maxima. One of the possible solution is to preshape the signal what can be tested off-line on collected raw signals. The ToT is also sensitive to baseline level and pile ups.

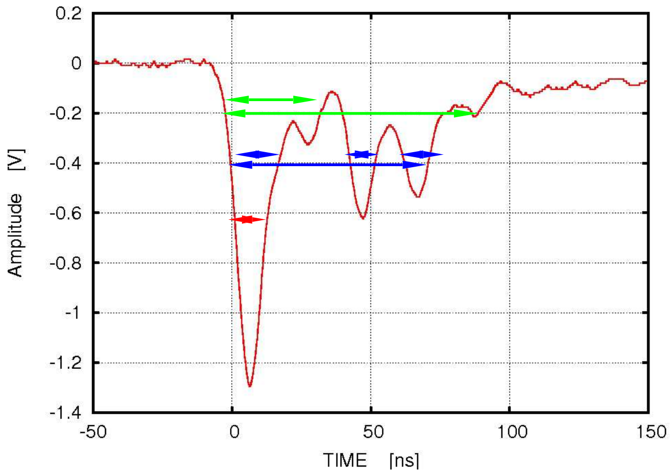

Figure 6: Time over Threshold method. Different "ToT" are shown for different thresholds.

The distribution of the energy losses is described by the Landau distribution (solid line on Fig. 7).

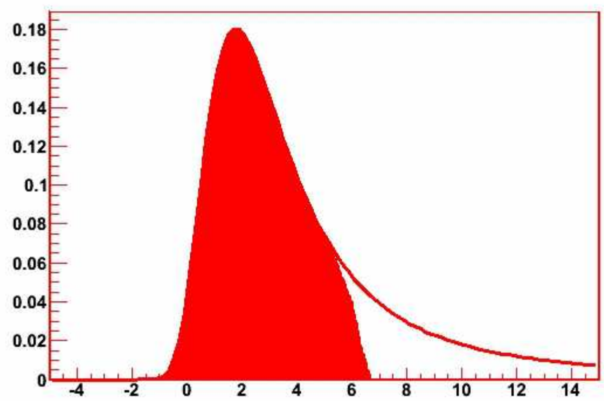

Figure 7: Distribution of energy losses measured in detector in arbitrary units before (solid line) and after (read area) applying of the truncated mean method.

The Landau distribution has a long tail which influences the separation of particles. The common method to reduce this tail is to reject signals with largest energy loss and make energy loss distribution more "gaussian" (red area on Fig. 7) – truncated mean method [9]. Different truncation values can be used. For applying this method energy loss information from different straw tubes are needed.

Other method discussed in literature is cluster counting method [10]. In this method the primary ionization cluster are counted (see Fig. 8).

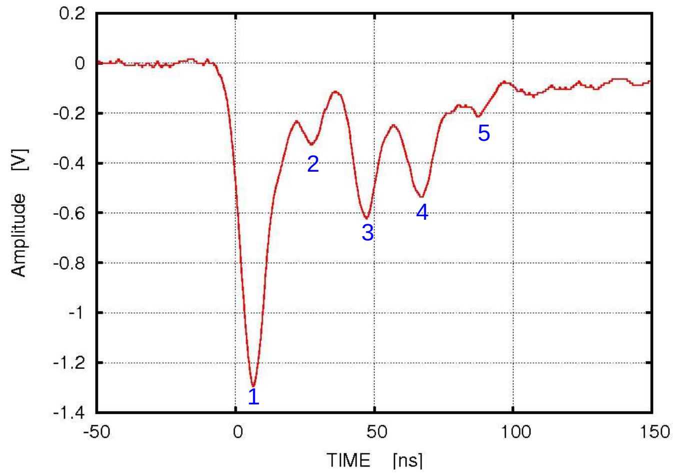

Figure 8: Particle identification by cluster counting.

This method needs long particle path in the gas volume to make the difference of particles type visible. For the straw tube one has to count primary ionization clusters from many tubes together. Fast preamplifier and comparably high digitalization frequency are needed to obtain good information. The advantage of cluster counting is that their are Poisson distributed and problem with Landau long tail is omitted.

4.2 Extraction of time information

In Fig. 9 different time extraction method are presented.

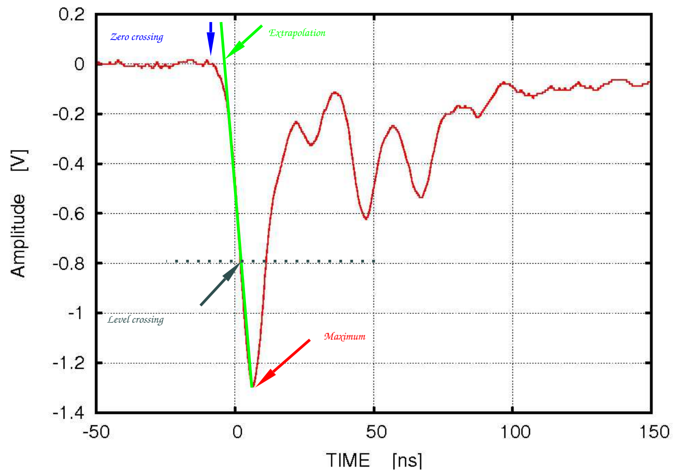

Figure 9: Different time extraction methods.

One of the simplest method is to determine the time when the signal crosses a selected level (dotted line on Fig. 9). The extracted time depend on signal amplitude (time walk). For the signal with constant rise time the constant fraction method (determine the time of crossing selected fraction of the amplitude) reduce significantly a time walk.

Taking into account signal shape extrapolation techniques can be used. Different number of digitalized signal points and different functions describing signal form can be used. In the simplest version it is the linear extrapolation and zero crossing (green line on Fig. 9).

Time of signal maximum (minimum) (red arrow on Fig. 9) has large time walking but in case of signal pile ups can be used as additional information to improve tracking and energy loss determination.

5. Summary and outlook

The use of fast 240 MHz 12–bit sampling ADC for collecting raw data allow us to develop, tests and optimize different techniques of identification and tracking of the particle without need to collect every time new experimental data with dedicated electronic setup. This make the development faster and efficient. The test setup is installed at COSY. First data with proton beam are already collected. Test of algorithms with different settings (HV, gas mixture, gas pressure, detector orientation, beam energy) are in preparation.

Acknowledgments

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