PANDA Straw Tube Detectors and Readout

P.Strzempek[a,*], for the PANDA Collaboration[b]

[a] Jagiellonian University, Krakow, Poland
[b] http://www.byteserver.org/download/panda_authors.pdf

Abstract

PANDA is a detector under construction dedicated to studies of production and interaction of particles in the charmonium mass range using antiproton beams in the momentum range of $1.5 - 15\ GeV/c$ at the Facility for Antiproton and Ion Research (FAIR) in Darmstadt. PANDA consists of two spectrometers: a Target Spectrometer with a superconducting solenoid and a Forward Spectrometer using a large dipole magnet and covering the most forward angles ($\Theta < 10^o$). In both spectrometers, the particle's trajectories in the magnetic field are measured using self-supporting straw tube detectors. The expected high count rates, reaching up to 1 MHz/straw, are one of the main challenges for the detectors and associated readout electronics. The article presents the readout chain of the tracking system and the results of tests performed with realistic prototype setups. The readout chain consists of a newly developed ASIC chip (PASTTREC $< PANDASTTReadoutChip >$) with amplification, signal shaping, tail cancellation, discriminator stages and Time Readout Boards as digitizer boards.

Keywords: PASTTREC chip, straw tube detector

1. Introduction

PANDA [1] is an experiment designed for research with antiproton beams, to carry out precise spectroscopy of charmonium and of open charmed mesons and hyperons, searching for new exotic states and investigating the proton internal structure. The studies will be done using antiproton-proton and antiproton-nucleus collisions at interaction rates reaching up to 20 MHz. A central part of the detector is a tracking system covering almost the full solid angle. It is composed of the Central Tracker (CT) [2] being part of the Target Spectrometer, which will reconstruct particle trajectories emitted from 22^o to 140^o polar angles with respect to the beam axis, and the Forward Tracker (FT) covering the most forward scattering angles. Both tracking systems are based on self-supporting straw tubes modules. The straws are designed to operate with high rates and have a minimal material budget of 0.044% radiation length.

2. Front-end electronics and readout

The main challenge for the operation of the straw tube detectors is a high rate environment which may lead to the overlap of signals coming from two different particles. This effect sets a requirement for fast shaping of the signals from the detectors by front-end electronics. Proper shaping and cancellation of the slow signal component originating from ions (see Fig. 1) enables processing data at high rates but also imposes a requirement for reliable and fast readout which is provided by Trigger and Readout Board (TRB version 3) [3](see description below).

*Corresponding author
Email address: pawel.strzempek@uj.edu.pl (P.Strzempek)

2.1. Front-end electronics (FEE)

The first stage of the electronics, which receives the signals from the straw tubes, is based on a 8 channel PASTTREC chip, designed specially for PANDA. The signals are shaped, amplified and discriminated with a constant threshold asserted by an integrated DAC. Detected rising and falling edges of the shaped signal are then sent to the TRB, to extract the drift time and Time over Threshold (ToT) information. To avoid problems with noise, the electrical standard between FEE and TRB3 is LVDS (Low Voltage Differential Signaling).

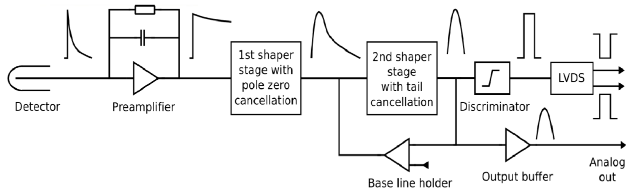

Figure 1: Block diagram of the PASTTREC chip.

2.2. Readout platform

The time measurement is performed by TRB3 boards. It is an FPGA based board with four edge FPGAs and a central one responsible for the communication and the data transfer assured by GbE reaching data rates up to 130MB/s. The edge units are able to provide various functionalities, depending on the installed firmware, but the most important for this application is a TDC providing 48 channels with a high resolution (20 ps) time measurement.

3. Prototype results

The readout electronics, described in the previous section, was tested with prototypes of the CT and the FT detectors by radioactive sources, cosmic rays and in-beam experiments. The latter ones have been performed using the proton beams with 0.6, 0.8, 2.95 GeV/c momenta at COSY (Jülich Forschungszentrum). The counting rates per straw tube were in order of 250–500 kHz. The main goal of the tests was to check if the tracking system can reconstruct the particle tracks with a precision of 150 μm (using drift time information) and identify the particles based on a charge measurement using the ToT information.

3.1. Charge measurement

Even though the ionization charge is not measured directly by the electronics, it can be estimated using the ToT information which depends on the amplitude of the analog signal generated by the straw. This dependency was estimated by illuminating the detector with a $55Fe$ source and operating the straw tubes at various high voltage settings. Knowing the primary ionisation and the gain for a given voltage, the produced charge has been calculated. The obtained relation between measured ToT of the X-ray absorption line and the charge is shown in Fig. 2.

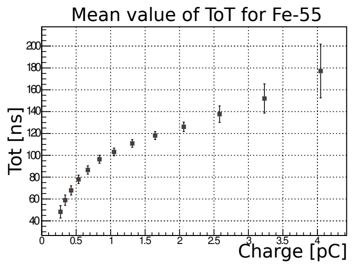

Figure 2: Time-over-threshold and charge correlation. Data taken with a 55Fe source. The correlation is used to translate the ToT to charge values.

3.2. Spatial resolution

In order to reach a momentum resolution of the tracking system of about 1%, a position resolution in a single straw of about 150 μm is required. To measure the resolution, proton tracks from the beam, that crossed a set of 20 straw tubes, have been reconstructed. The difference between track position in a given tube and position extracted from the drift time measurement (residual distribution) is shown in Fig. 3. It confirms that the required resolution is almost achieved.

3.3. Particle identification

The specific energy loss in the CT can be used for particle identification (PID). The PID information from the CT is needed in particular to separate protons, kaons and pions in the momentum region below 1 GeV/c. In Fig. 4 the ToT/dx, that is related to the total energy loss, is presented for different beam momenta measured in the same experiment. The ToT/dx is calculated as the sum of ToT's measured in straws which hits have

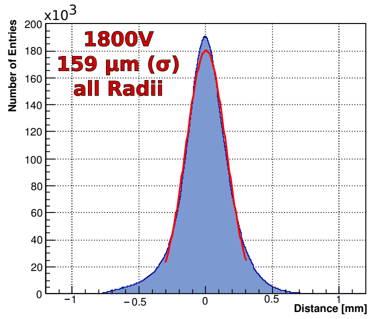

Figure 3: Residual distribution. The spatial resolution is defined as the sigma of a Gaussian fit and is around 160 μm.

been assigned to the same trajectory. A clear increase of the TOT/dx as a function of the decreasing beam momentum is observed in accordance to the expected energy loss dependence.

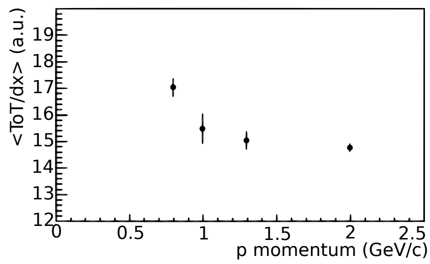

Figure 4: ToT/dx for different beam momenta.

3.4. Summary

In the article the prototype detectors and the readout for the PANDA tracking system as well as the first test results have been presented. In particular it has been shown that:

+ the detectors work properly at high count rates and the front-end electronics is suitable for signal amplification, shaping and discrimination,

+ the desired spatial resolution (150 μm) for CT was almost reached,

+ the particle identification based on the ToT information is feasible after appropriate calibration.

Acknowledgments

The project was financially supported by the National Science Center Poland based on decision number DEC-2013/09/N/ST2/02180

References

[1] PANDA collaboration, Letter of intent for PANDA- Strong Interaction Studies with Antiprotons, Technical report FAIR-ESAC, (2004).

[2] W. Erni et al., Technical Design Report for the: PANDA Straw Tube Tracker, arXiv:1205.5441, Eur. Phys. J. A (2013) 49: 25, DOI: 10.1140/epja/i2013-13025-8

[3] Ugur C. et al.(2013) 264 Channel TDC Platform Applying 65 Channel High Precision (7.2 ps RMS) FPGA Based TDCs. IEEE Mediteranean Workshop on Time to Digital Converters.