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Readout Electronics for TPC

R. Janik, P. Strmeň, I. Szarka

Department of Nuclear Physics and Biophysics, Faculty of Mathematics, Physics and Informatics, Comenius University, 842 48 Bratislava, Slovak Republic

Abstract: New readout electronics for Time projection chambers used on Fragment Separator at GSI Darmstadt has been built. The electronics fulfill all the demands for highly sophisticated coordinate detectors – TPC.
A special NIM module was developed for 6 channels of TPC. ″Ampl./Disc. TPC Module″ contains linear amplifier-shaper with adjustable gain of 4 30 and the maximum output signal of 8 V. It contains also Zero-crosser discriminator, timing on the signal maximum with adjustable threshold 50 mV 1 V. A digital delay up to 1 μs and NIM-ECL adapter are included in each channel.
New electronic module was used instead of several conventional modules in many experiments on study of exotic nuclei on FRS. The electronics is characterized by high performance and reliability.

1. Introduction

Majority of experiments in physics use gas coordinate detectors for precise particle or ion track measurements. In many cases these detectors are running at high beam intensities, which require optimization of parameters (both of detectors and electronics).

On the fragment separator (FRS) at GSI Darmstadt, multi-wire proportional chambers were used in the past as a position sensitive detector in experiments on heavy ion beams. While designing new experiments to study halo nuclei, we found that these detectors are not suitable due to requirements on precision, homogeneity and construction. Time-Projection Chamber (TPC) has been designed and developed as a substitute, modified for use in experiments with exotic nuclei [1].

The optimum data collection from detectors depends highly on linear electronics, which needs to be designed and carried out in line with requirements on certain detector. If using standard electronic blocks, which are produced for universal use, the optimum signal path cannot be usually established. This is the reason why special electronic blocks need to be designed and produced for the optimum collection and processing of information.

While choosing the detector type, detector and read-out electronics price plays a significant role. That is why we chose TPC type of chamber with delay lines [DL], where only 6 electronic channels are needed for precise determination of coordinates. Furthermore, such detectors are capable to identify fragments from studied reactions effectively.

2. Delay lines

Avalanche localization along the wire (coordinate x) in TPC chamber is measured on the cathode, which may comprise wound delay line (DL), or segmented cathode is used,

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Devoted to Prof. Pavel Povinec 65-th anniversary which comprises separated stripes. Individual stripes are connected by integrated “dual in line“ DL with focused parameters.

Since DL (either wound or integrated) and input resistance of preamplifiers are not identical (they vary by RLC values), each DL needs to be adjusted (terminated) together with preamplifier and, thus, minimize heterogeneity of the wiring and reflections.

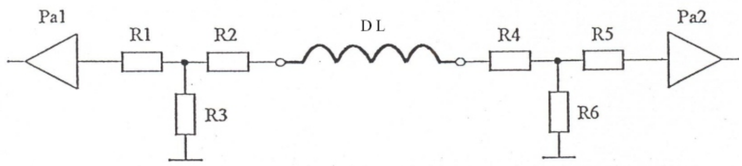

Fig. 1. Diagram of wound DL set-up.

In case of wound DL, the adjustment is carried out by T elements on both ends of DL (Fig. 1). The adjustment on integrated DL is made by termination impedance Z_0 (Fig. 2).

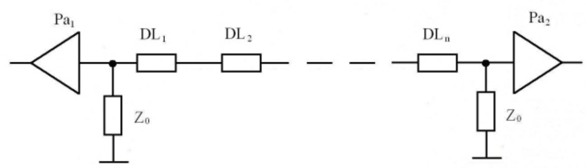

Fig. 2. Diagram of integrated DL set-up.

Fig. 3 shows a signal from adjusted DL. Fig. 4 shows that non-terminated DL is not applicable for coordinate measurement. Wound DL used in TPC chamber is one of the solutions to measure beam coordinates on the axis x. Lots of effort, however, need to be exerted to fulfill required criteria. Signal induced on flat delay line is relatively small (approximately 15 % of the anode signal). This calls for operation with high detector gas amplification. Large gas amplification limits the use of detector at high beam intensities, because a high quantity of space charge emerges inside the detector, which originates a shift of amplitude spectra.

This motivated improvements in the cathode read-out system. Differently shaped strip cathodes instead of a flat one were designed and produced. Measurements shown that the highest induced signal may be achieved on the strip cathode shaped to C pads. In this case, induced charge on the full cathode increased four times up to 70 % of anode signal.

3. Front end electronics

It was necessary to design and carry out two types of preamplifiers for signal processing from anodes (for amplitude analysis) and from cathodes (for time analysis). The “anode preamplifier” is processes a negative signal from anodes while the “cathode

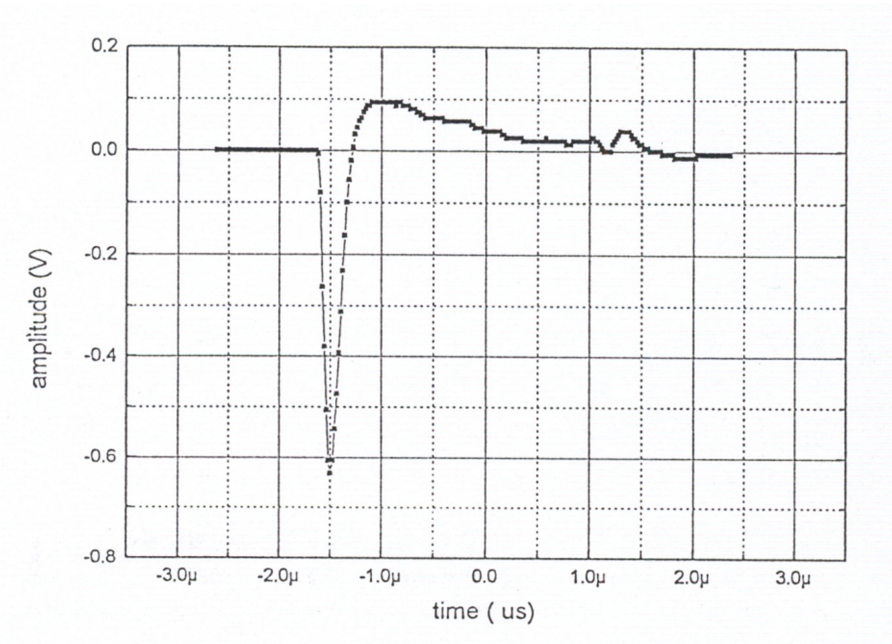

Fig. 3. Signal from adjusted DL.

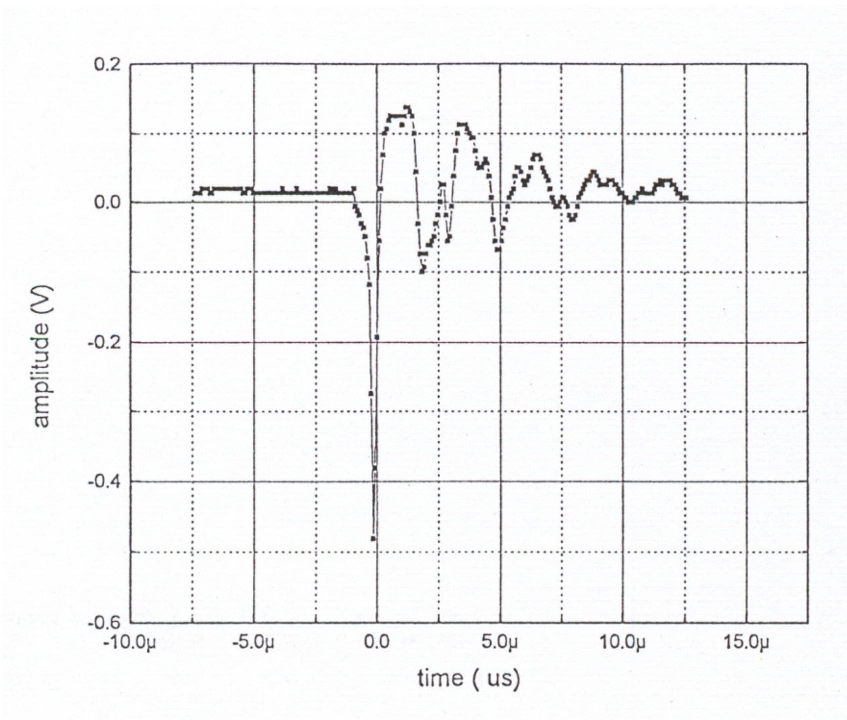

Fig. 4. Signal from non-adjusted DL.

preamplifier" is processes a positive signal from cathode. Signal induced on the flat cathode is significantly smaller than the one on the anode and of reversed polarity.

DC coupled, charge sensitive preamplifiers-shapers with negative feedback are used. These were produced by SMD technology (surface assembly), which allowed to reduce the size significantly, and in the same time, to improve its parameters. For this reason, they could have been located directly on the anodes and delay limes inside the detector. This solution along with output impedance of 50 (for coaxial wiring) improved signal/noise and signal/pick-up ratios, which is a very important feature for further processing of signals.

Parameters of preamplifiers:

	Anode preamp.	Cathode preamp.
Amplification	1 V/pC	6 V/pC
Input resistance	1 k	1.2 k
Output resistance	50	50
Intrinsic noise	3 mV	10mV
Leading edge	40 ns	30 ns
Signal length	250 ns	250 ns
Polarity of input signal	negative	positive
Polarity of output signal	negative	negative
Integral non-linearity	< 1 %	< 1 %

Shapes of signal from cathode and anode preamplifier, measured directly on particles beam by digital oscilloscope, are shown in Figs. 5 and 6. The overshoot before leading edge of a signal caused by DL non-homogeneity, is visible in Fig. 5.

For signal amplitude analysis, a high linearity is needed in the whole electronics chain from the preamplifier up to the ADC.

Fig. 7 shows the fitted curve of integral non-linearity of cathode preamplifier, which is on the level of only 0.8 %.

High linearity of our preamplifiers is also documented in Fig. 8, which shows the dependence of gas amplification and anode signal amplitude on anode voltage. ^{55}Fe source was used in the measurements. This picture also documents that TPC chamber operated in purely proportional mode.

4. Read-out and signal processing electronics

Signal from the detector (from preamplifiers) is sent by approximately 100 m long coaxial cable to experimental room of Fragment Separator (FRS) at GSI Darmstadt. This signal needs to be further amplified shaped and adjusted for inputs of standard electronics blocks in the system VME (ADC: CAEN V785, TDC: CAEN V775). This type of ADC needs for its full range linear input signal amplitude up to +8 V, TDC requires input signal through twisted pairs with ECL standard level.

In the past were used on FRS on the signal path between the output of preamplifier and ADC and TDC several commercially produced blocks (linear amplifier with adjustable gain, Constant Fraction Discriminator, Delay and Converter NIM-ECL). To optimize electronic path of signal and to increase the reliability, a special electronic block was pro-

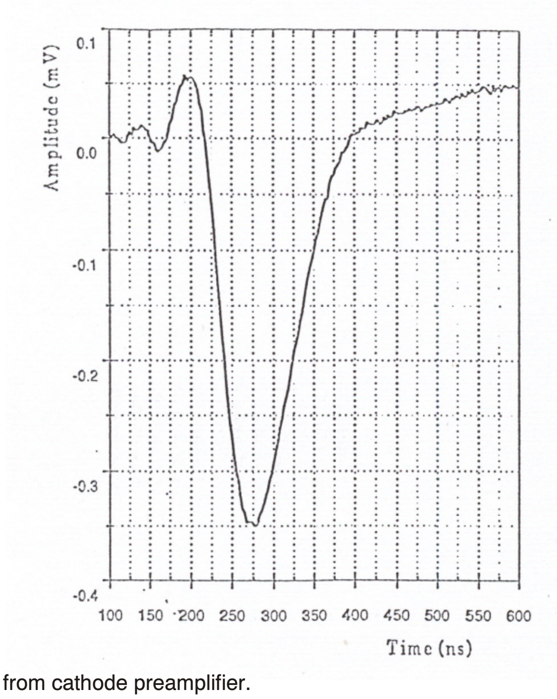

Fig. 5. Signal shape from cathode preamplifier.

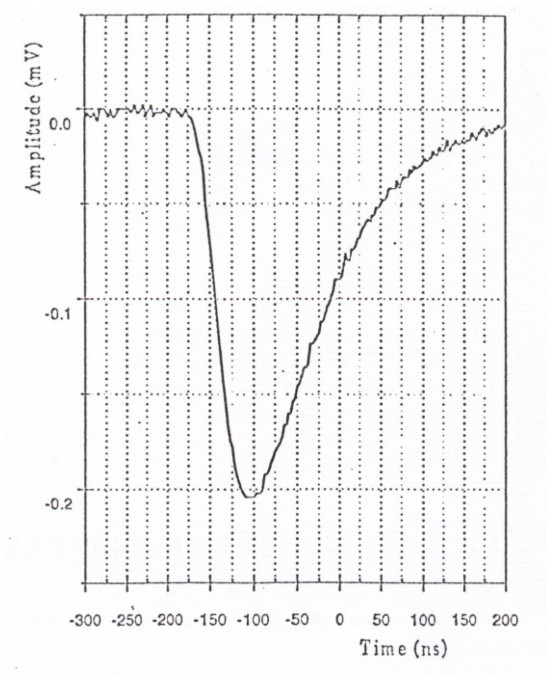

Fig. 6. Signal shape from anode preamplifier.

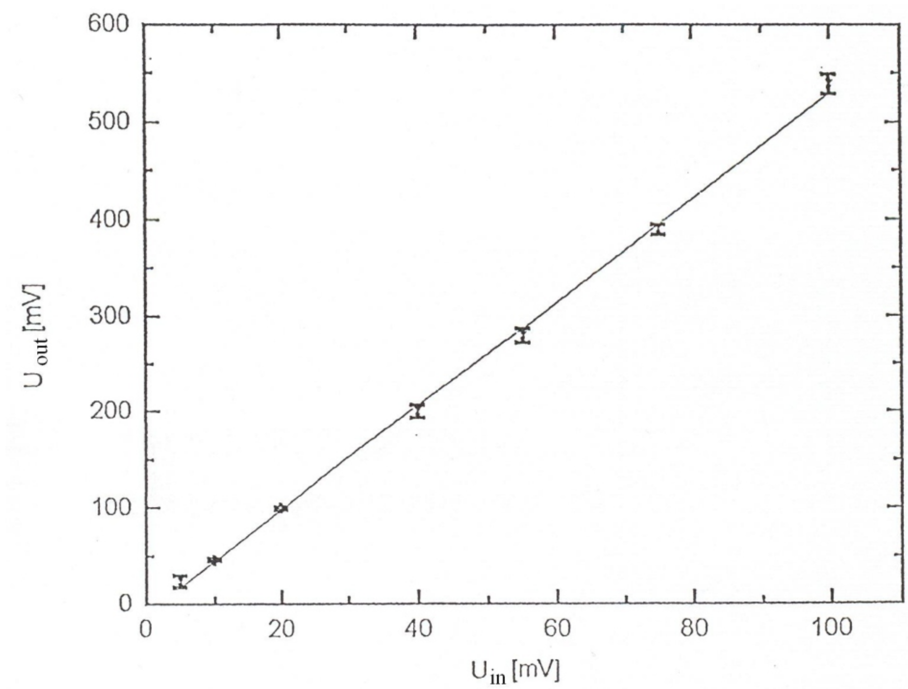

Fig. 7. Determination of integral non-linearity of cathode preamplifier.

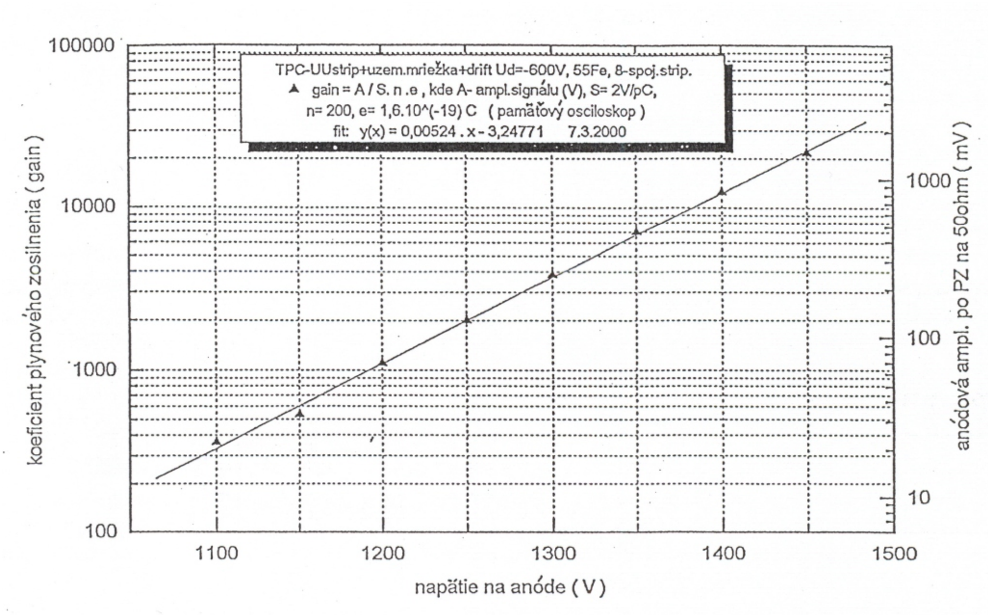

Fig. 8. Dependence of gas amplification and anode signal amplitude on the anode voltage.

duced (Ampl./Disc.TPC) in NIM standard, which replaced the above mentioned modules. Block diagram of a single module containing 6 channels is shown in Fig. 9.

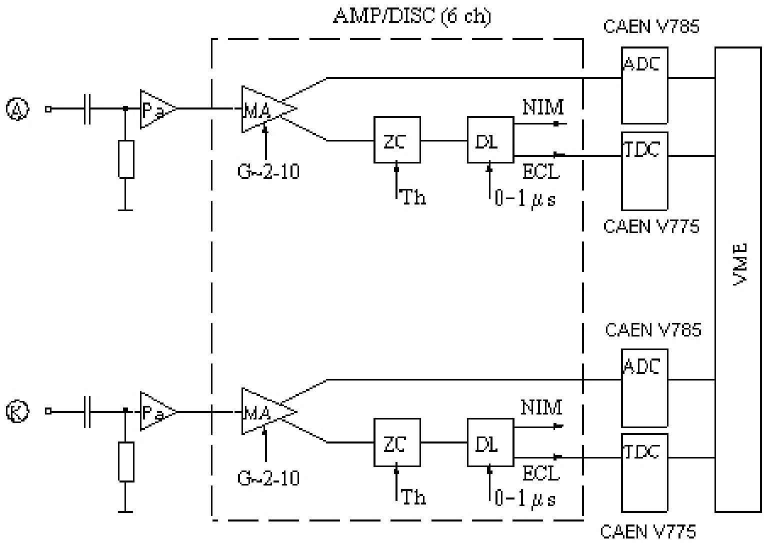

Fig. 9. Block diagram Ampl./Disc. TPC electronics.

Signal from preamplifier comes to the input of linear amplifier with adjustable gain (G ~ 2 30). From the amplifier, the linear positive signal comes to ADC input (max. amplitude +8 V) and the negative signal to discriminator input (max. amplitude -2 V), in which necessary discrimination level of signal may be adjusted.

Since signals forming delay lines are quite long, they are shaped to 250 ns and Constant Fraction (CF) Discriminator with large jitter is not an ideal solution for this type of signals. For these reasons a discriminator operating on the “Zero crosser” (ZC) principle has been designed. This ensures that output signal for TDC timing follows the peak (maximum) of the analog input signal. The time jitter from Zero crosser discriminator is considerably smaller than from usual leading edge, or CF discriminators. Our ZC discriminator is giving highly precise time response of output digtal (NIM standard) signal even for leading edges of input signals up to 150 ns.

Parameters of Zero Crosser Discriminator:

Input resistance	50
Input signal polarity	negative
Input signal amplitude	50 mV–2V
Output signal shape	NIM (50 ns)
Output signal jitter	0.8 ns
Number of channels in a block	6

In the experiments on FRS a master trigger produced in several different detectors and electronic blocks is delayed. For this reason signals from TPC may be delayed as much as 1 s before coming to ADC and TDC. The part of a new block is also an NIM-ECL converter. The new block has 3 outputs. One is linear, one is a NIM standard and one is an ECL for twisted pairs.

4. Conclusions

The electronics fulfill all the demands for highly sophisticated co-ordinate detectors – TPC. Seven new electronic blocks were used instead of several conventional modules in many experiments on study of exotic nuclei on FRS [2 5]. The electronics is characterized by high performance and reliability.

Acknowledgement

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