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Study of Analog-to-Digital converters for the TPC prototype for ALICE.

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Abstract

The performance of several ADCs has been studied using signals from the preamplifier designed for the ALICE TPC. The experimental setup and the evaluation procedure are described. Results leading to the selection of the ADC chip for the TPC prototype are presented.

1 Introduction

One of the milestones of the design and construction of the large Time Projection Chamber (TPC) for the ALICE experiment is a smaller-scale prototype detector. It will be used as forward TPC of the NA49 experiment running with proton and ion beams at CERN [1]. The prototype TPC is designed to incorporate the main features of the full-size detector. The readout elements, Ring Cathode Chambers (RCC), will be mounted on a multilayer printed board, to which preamplifier chips [2] will be fixed. The preamplifiers will be connected by 2 meters long co-axial cable of small diameter ($\simeq$ 0.51mm, produced by AXON) to Analog-to-Digital Converters (ADC). After receiving a trigger an ADC will start measuring amplitude of input signal at fixed time intervals. To cover drift length of the full scale TPC one thousand measurements will be taken. Pulses corresponding to different ionization deposits will be sampled at various points along the waveform. Therefore a pulse shape measured by an ADC should reproduce an input pulse shape without distortions. The simplest choice for the ADC would be to use a flash ADC. This is not possible due to high power consumption (e.g. 2.8W for Analog Devices AD9060). Other architectures, like half-flash used in Harris HI5710 or differential pipe-line (Analog Devices AD9200), offer smaller power consumption, respectively 140 mW and 80 mW. The readout of the prototype TPC will be integrated into the NA49 experiment acquisition system.

In this note results of the evaluation of ADC chips for the prototype TPC are presented. The experimental setup is described in section 2, results are shown in section 3 followed by conclusions in section 4.

2 Experimental setup

The ALICE TPC requires an ADC with 10 bit dynamic range [3].

The following commercially available ADCs were preselected:

- AD9200 produced by Analog Devices
- HI5710 by Harris Semiconductor
- TDA8766 by Philips Semiconductors

These ADC chips have been subjected to a standard test procedure with sine wave input [4] to provide independent verification of the information provided by the manufacturers.

The signal from the particle detector is more complicated than a sine wave. Therefore tests with a realistic input, similar to the pulse from the TPC readout chamber passing through a preamplifier-shaper, are necessary.

The experimental setup is shown in Figure 1. The ADC chips were mounted on small printed circuit boards housed in the CAMAC ADC evaluation board [5]. Up to four (different) ADC chips with different analog inputs could be tested at the same time. After the trigger signal was received a predefined number of samples (ADC digitisations) were taken and digital results stored in the local memories to be readout by a LabView programme run on Macintosh Quadra 650. A CERN MAC-CC CAMAC controller with the MacVEE NuBus A410 card by Bergoz was used.

We used the following inputs to the ADC:

- Pedestal : no input at all (ADC input terminated with 50Ω), or a preamplifier-shaper connected with no input signal to it. It was used to study the noise of the system.
- Rectangle : a rectangular pulse with predefined amplitude.
- "Pasa" : a rectangular pulse was passed through a differentiating RC circuit (15pF, 50Ω). The resulting "delta function" signal was passed through the preamplifier-shaper. This signal is similar (except for the trailing edge) to the one from a single electron detected in a proportional chamber. In a TPC detector one can expect slower rise time in comparison to a single electron signal due to the charge diffusion during drift and/or track inclination with respect to the readout chamber. Therefore the "Pasa" signal corresponds to the fastest rise time to be expected from a real detector.
- "Pulser" : the shape of the "Pasa" signal described above was transferred from the digital oscilloscope to LW420A, the waveform generator produced by LeCroy. The generator, controlled via GPIB interface from a Macintosh, was able to produce a signal of such shape with different amplitudes.

We delayed the signal with respect to the trigger using a precise programmable delay unit (4222 PDG by LeCroy).

The following triggers were used:

- Trigger 1. Pedestal trigger from a 1kHz clock [6].
- Trigger 2. The signal trigger was synchronised with the ADC clock. Synchronisation was necessary to avoid fluctuation of the position of the digitisation point with respect to the beginning of signal pulse.

3 Results

- Noise performance.

  The ADC input was terminated with 50Ω and Trigger 1 was used. For each trigger 999 digitisations were taken. The distribution of the mean amplitude for each digitisation for 1000 triggers as a function of the digitisation number n is shown in Fig. 2. A repetitive pattern with frequency of 1.6MHz is superimposed on a constant noise level. Depending on the digitisation number n the RMS of noise was between 0.5 and 0.8 ADC counts (LSB), with a mean value of 0.52 LSB. This effect was observed for all tested ADCs. Correlation of the noise pattern with the digitisation number n suggested that pickup came from the digital activity on the ADC test board.

- Dynamical performance.

  To study the dynamical performance of the ADC, Trigger 2 was used with the "PASA" and "Pulser" signals.

  The time distance of 100 ns (ADC sampling rate was 10 MHz) between subsequent digitisations is far too big for a precise study of the shape of digitised signal and check for its possible distortions introduced by the ADC. Therefore we have chosen to delay the signal with respect to the trigger to study the output pulse shape.

  The comparison of signal shape for different amplitudes with the input signal is shown in Fig. 3 for Harris and Philips ADCs. The distributions for Harris show correct behaviour of the ADC and similar results were obtained for Analog Devices. However, for amplitude values close to full ADC range, the input pulse was distorted by the Philips ADC. The distortion occurred at the middle of the rise time, where the highest frequency components contribute to the pulse shape. According to specifications, one expects bandwidth limitations to show-up in this region. In Fig. 4 the distribution of ADC values for the input signal at the middle of the rise time is presented. As already mentioned in Section 2 the pulse in a TPC detector will have a larger rise time and the Philips ADC may be found adequate for application in a large scale TPC.

- Linearity.

  The linearity of the Analog Devices and Harris ADCs was studied with the "Rectangle" and "Pulser" signal. The linearity curve and residuals from the fitted straight line are presented for Analog Devices in Figures 5 and 6 showing integral non-linearity of 1. ADC count, in accordance with the device specifications. The Harris ADC behaved in a similar way.

4 Conclusions

The dynamical performance, linearity and noise characteristics of TDA8766, HI5710 and AD9200 ADCs in the environment of the ADC evaluation board [5] was studied. A pulse produced by the preamplifier to be used for the ALICE TPC prototype was used as an input. The HI5710 and AD9200 should be adequate for use in the prototype of ALICE TPC.

References

[1] J.Bächler et al., CERN/SPSC 98-4,CERN/SPSLC/P264 Add. 2.

[2] designed by J-C.Legrand.

[3] N.Ahmad et al., ALICE Technical proposal, CERN/LHCC/95-71, LHCC/P3.

[4] J.C.Tarle and L.Musa private communication.

[5] J-C.Berset, C.Engster, L.Musa and J-C.Tarle, ADC Evaluation Board Reference Guide.

[6] designed by Arek Chłopik.

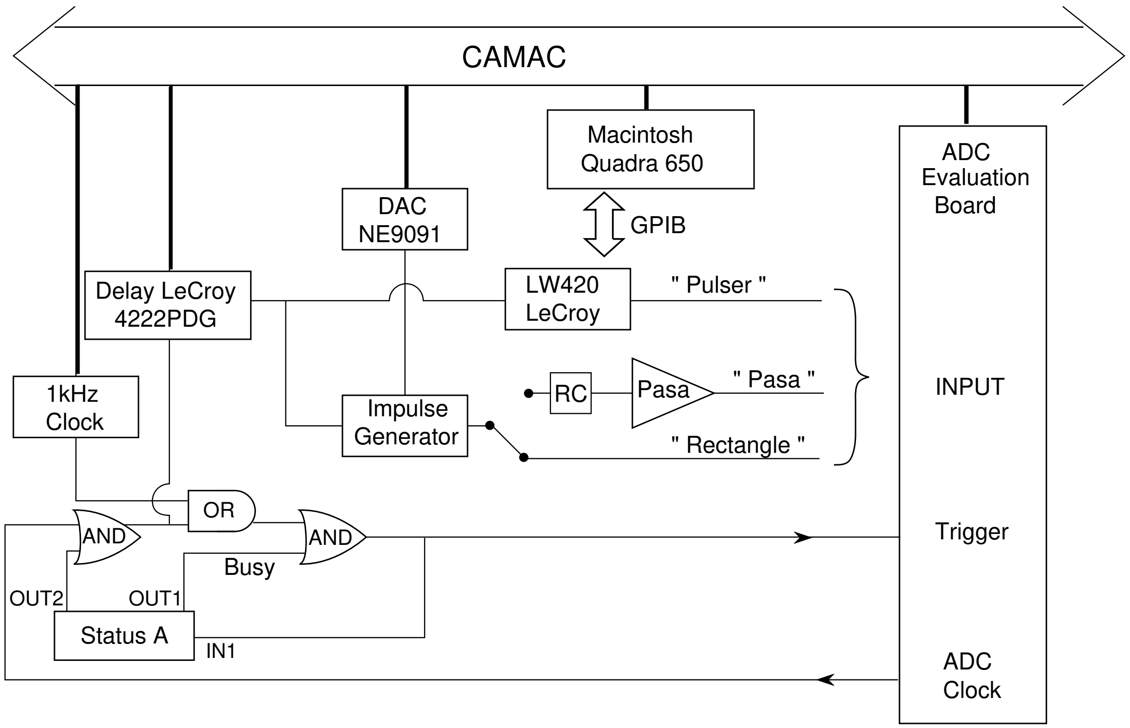

Figure 1: Experimental setup.

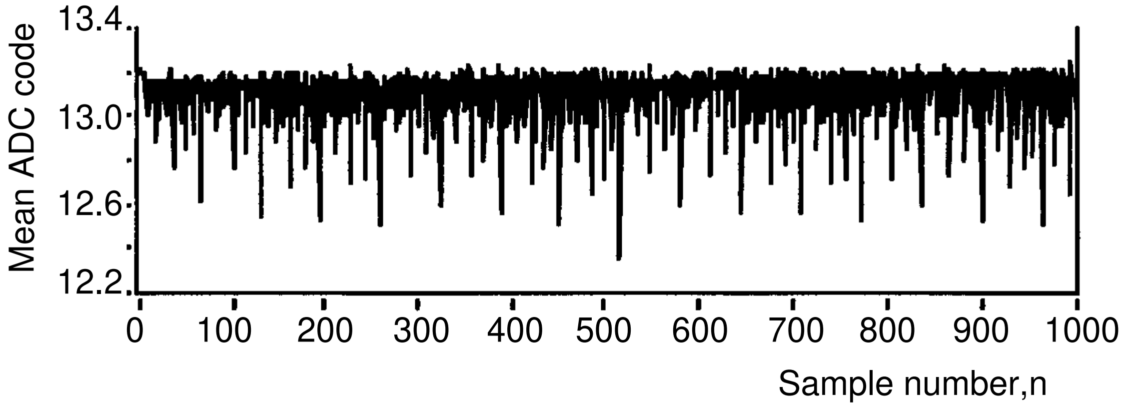

Figure 2: The distribution of the mean ADC code, with no input to the ADC, as a function of the digitisation number, n.

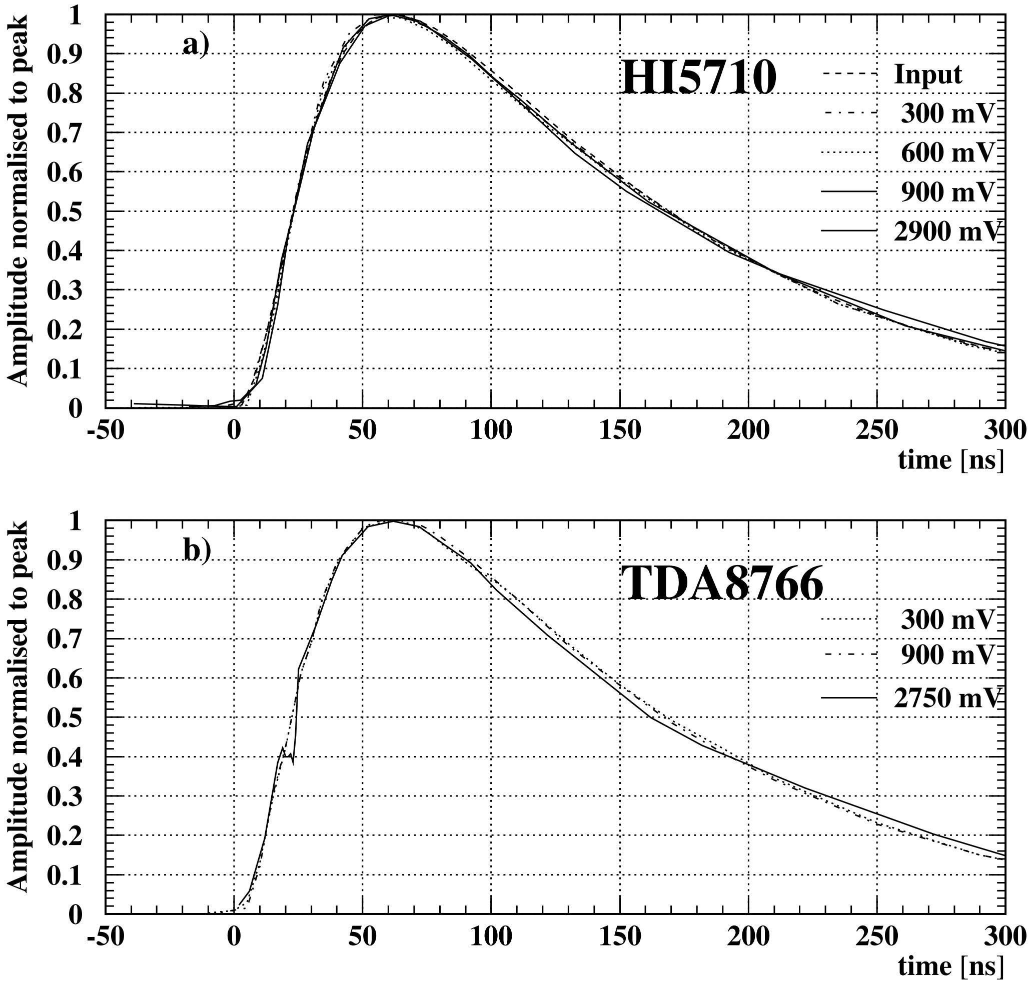

Figure 3: The pulse shape comparison of the input pulse and pulse measured by the ADC for different amplitudes of the input pulse: a) for Harris b) for Philips.

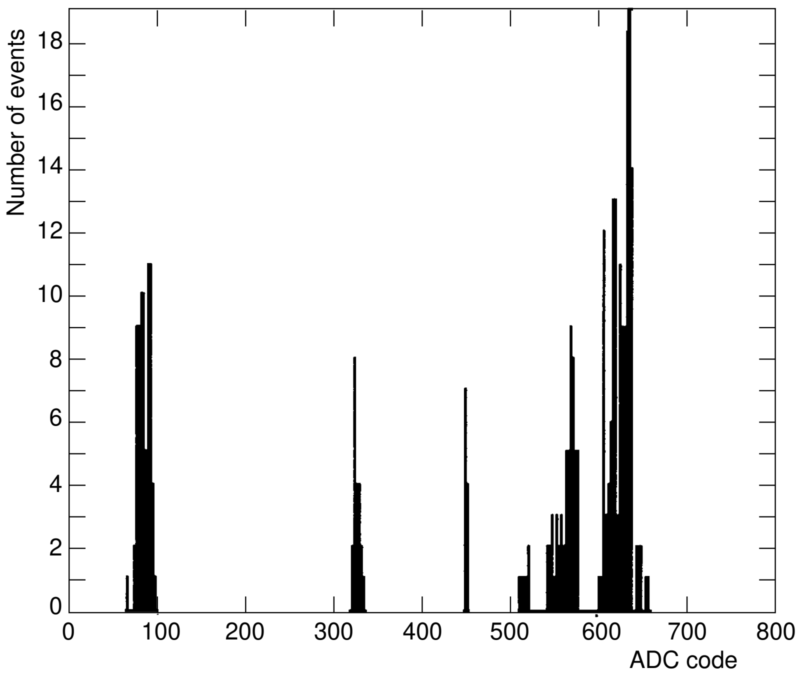

Figure 4: The distribution of the Philips ADC codes for the pulse sampled at the middle of the rise time (cf. Fig. 3b).

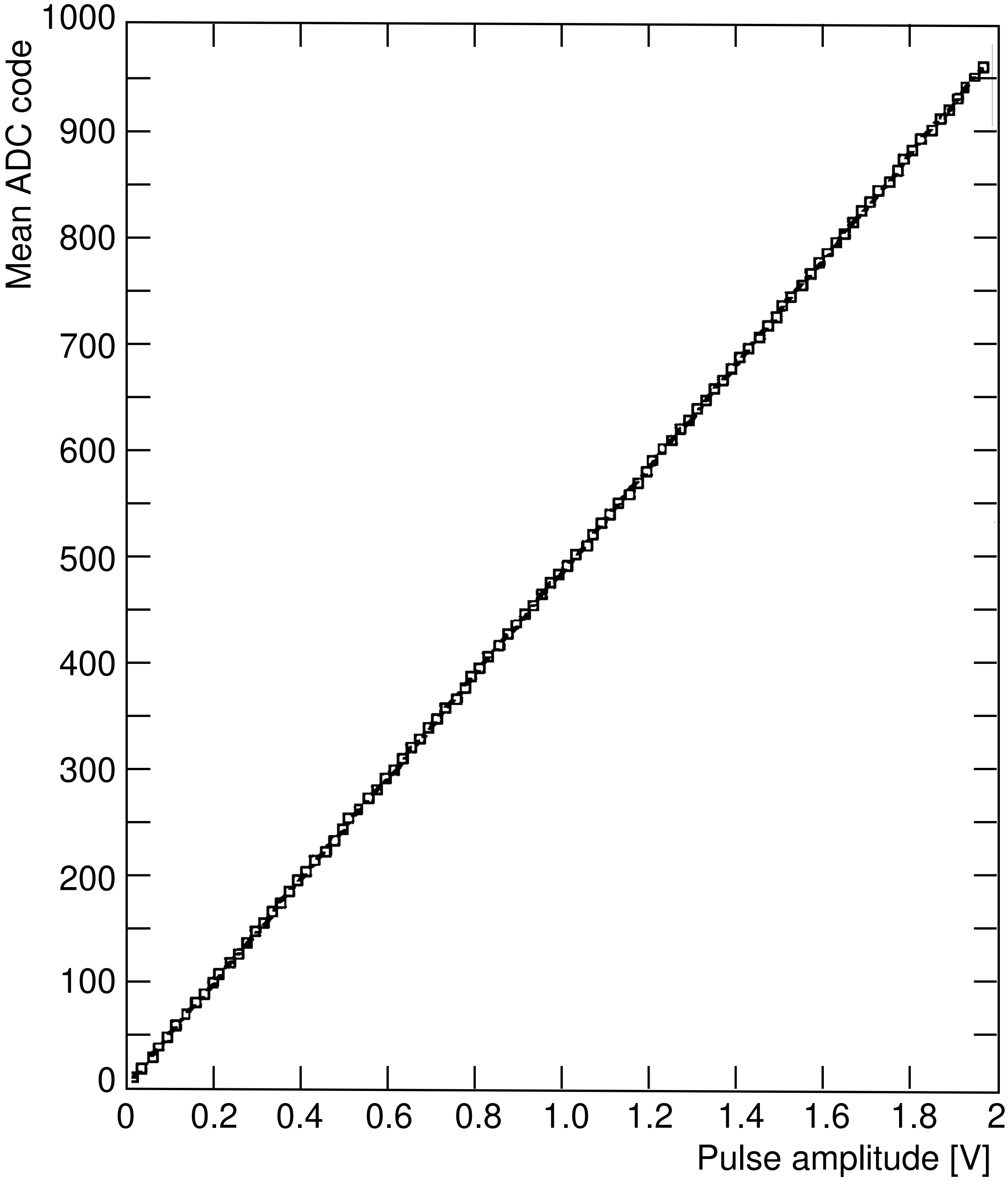

Figure 5: The Analog Devices response as a function of the input pulse amplitude.

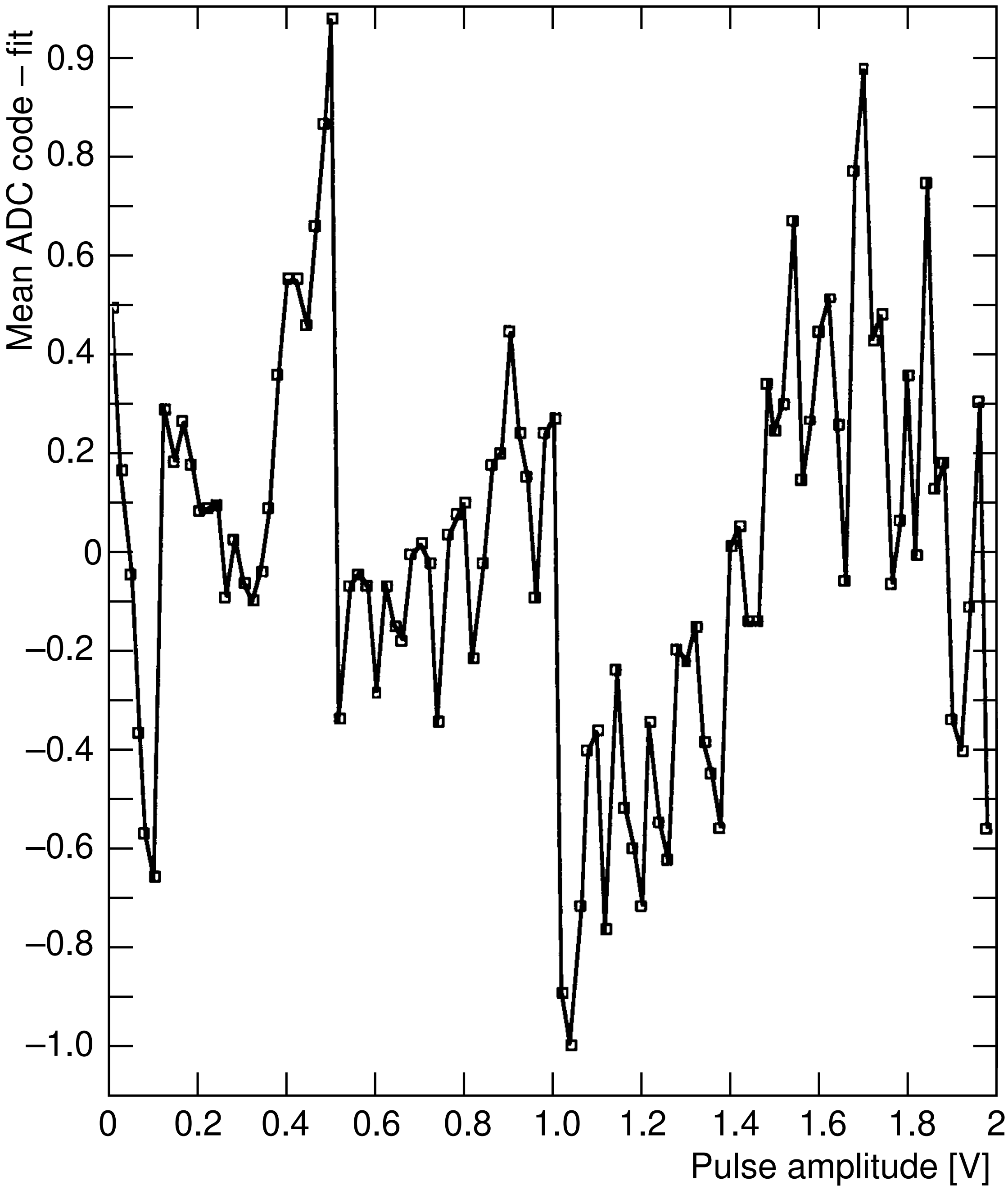

Figure 6: Difference between the Analog Devices response and the straight line fit (cf. Fig. 5)-lines are to guide an eye.