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ZEUS Luminosity Photon Calorimeter Linearity Measurement

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Abstract

Report presents the test results of the linearity measurement of the Luminosity Photon Calorimeter readout electronics. Nonlinearity of the preamplifiers, amplifiers, 140 meters long analog signal transmission, integrators and FADC have been measured and analyzed. This allows making data correction and results in increased luminosity measurement precision for off-line processing.

1 Introduction

Luminosity is one of the most important parameter of the collider and must be known precisely to evaluate absolute cross section from the observed event rates. The precision of the luminosity measurement is determined by the photon calorimeter energy resolution and readout electronics errors (i.e. nonlinearity, quantization, pedestal shifts). The quantization error can be easily taken to account for off-line processing. Pedestal shifts, mostly due to temperature change, have been subtracted on-line from data. For the off-line data processing it is possible to correct nonlinearity of the electronic chain also. We have performed several measurements of the readout electronics nonlinearity separated in time with different methods to avoid systematic errors. The tests have been done on 21.01.2006, 22.01.2006, 12.05.2006, 09.07.2007 and 11.07.2007.

The completely electronic chain (front-end amplifiers, cable drivers, 140 meters long analog transmission, cable receivers, integrators and FADC) except photomultipliers and preamplifiers have been measured. Additional tests have been done after end of Luminosity Monitor operation (end of HERA operation) including linearity measurement of the preamplifiers.

2 Measurement setup

Measurements have been done in the HERA tunnel using the Luminosity Monitor readout electronics, Data Acquisition System (DAQ) and three different measurement setups.

Light Test System based on two LED's type HLMP-EL24-PS00 and LT driver has been used to produce very short light pulses illuminating photocathode of R5330 photomultipliers (PMT) from Hamamatsu. The charge signals from the anodes of PMT's, amplified by the preamplifiers placed inside the photon calorimeter have been used as the input test signals for the readout chain. The LT pulses intensity can be controlled by Digital to Analog Converter (DAC), but the characteristics of the light amount produced by LED's versus DAC value is strongly nonlinear (see Fig.1.)

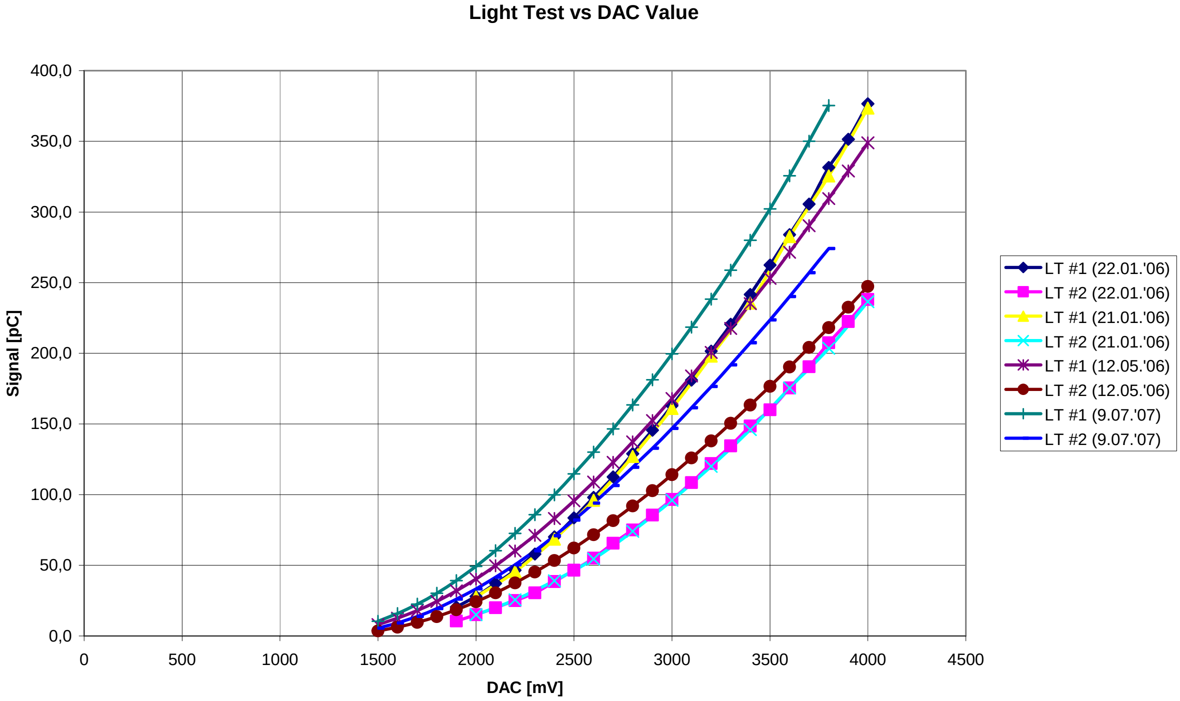

Fig.1. Charge signals from two channels of Photon Calorimeter versus Light Test DAC value.

We have used the current settings (i.e. HV values for PMT's) for the Luminosity Monitor readout electronics. It is clearly seen in Fig.1, that HV setting for PMT's have been changed between 21.01.2006 and 11.07.2007 (=> change of the PMT gain).
The Light Test stability over one day period is shown in Fig. 2. (no change of HV settings).

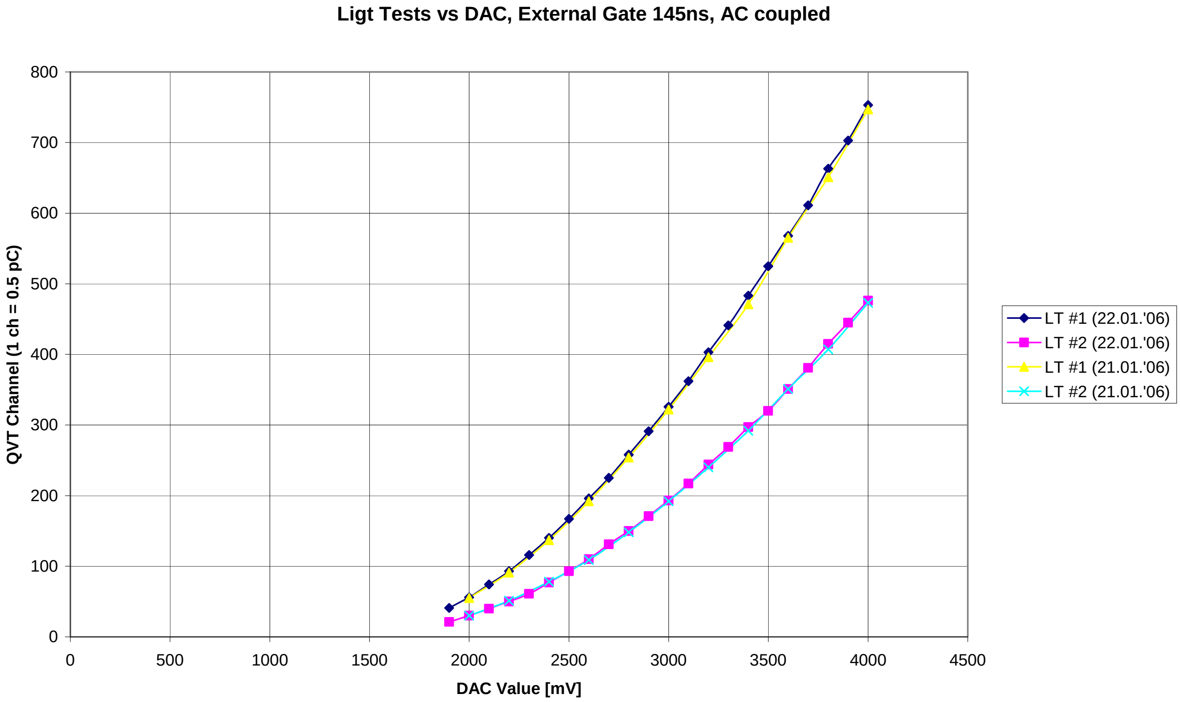

Fig.2. Stability of Light Test over 1 day period.

The idea is, to measure the charge pulses distribution for different DAC sets using Lumi DAQ and independent setup for the input pulses and calculate the nonlinearity of the readout chain.

2.1 Measurement setup I

A block diagram of the measurement setup I (21 & 22 January 2006) is shown in Fig.3.

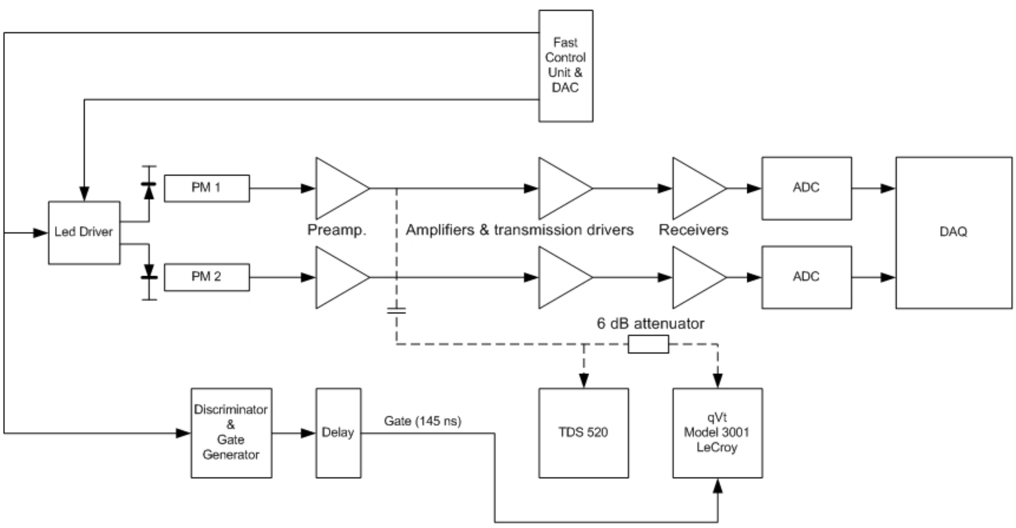

Fig.3. Block diagram of the linearity measurement setup using multichannel analyzer LeCroy qVt model 3001 and a Tektronix digital scope TDS 520A.

We have collected 5000 events for each point for different DAC values from 1900 mV to 4000 mV in 100 mV steps using multichannel analyzer LeCroy qVt model 3001 and, in parallel, Tektronix scope TDS 520A (mean value of 5000 pulses has been read out for each point). Using DAQ we have collected 10 000 events for each point for corresponding DAC settings. The qVt and TDS 520A have been AC coupled to subtract DC offset (6 dB attenuator has been necessary to fit the qVt scale) and pedestals have been subtracted from the DAQ data.

2.2 Measurement setup II

A block diagram of the measurement setup II (12 May 2006) is shown in Fig.4.

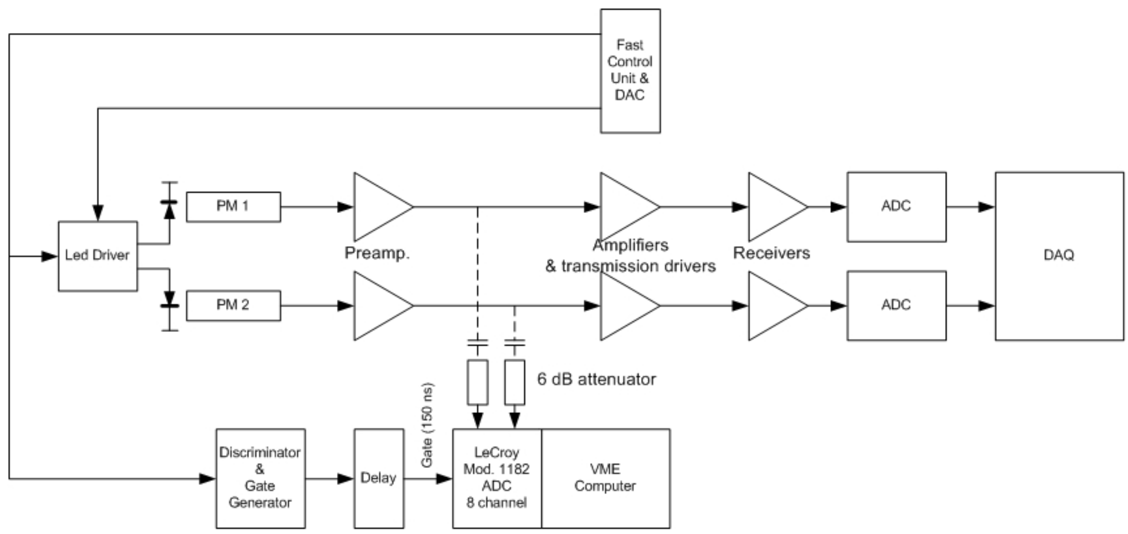

Fig.4. Block diagram of the linearity measurement setup using VME 8-channel LeCroy charge sensitive ADC model 1182.

We have collected 10 000 events for each point for different DAC values from 1500 mV to 4000 mV in 100 mV steps using VME 8-channel LeCroy charge sensitive ADC model 1182. Using Luminosity Monitor DAQ we have collected 10 000 events for each point for corresponding DAC settings. The 1182 ADC has been AC coupled to subtract DC offset and 6 dB attenuators have been necessary to fit the ADC scale. Pedestals have been subtracted from the DAQ data.

2.3 Measurement setup III

A block diagram of the measurement setup III (09 & 11 July 2007) is shown in Fig.5.

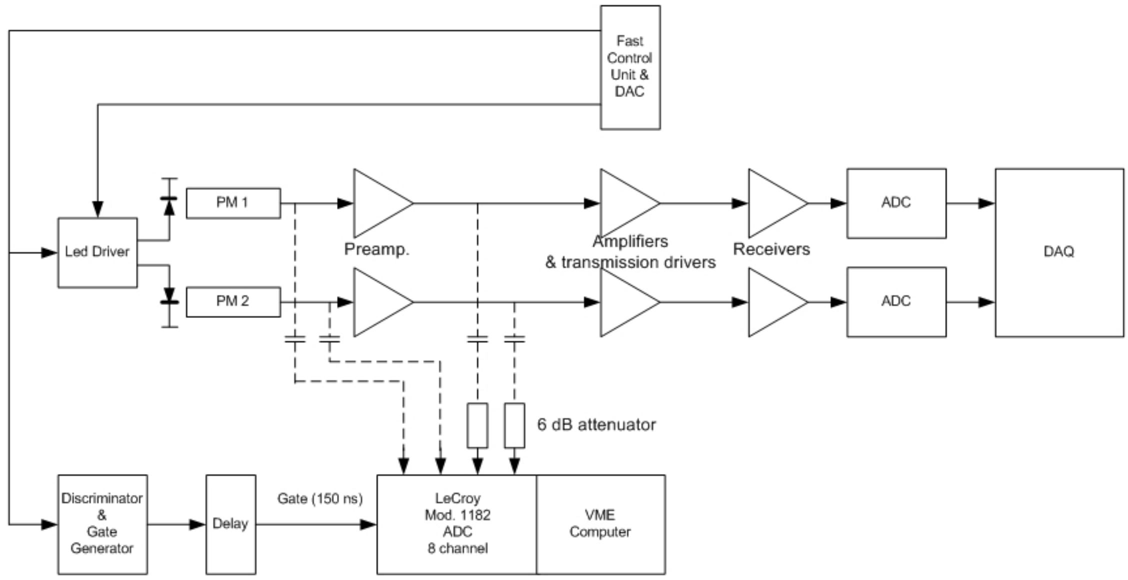

Fig.5. Block diagram of the linearity measurement setup including nonlinearity of preamplifiers using VME 8-channel LeCroy charge sensitive ADC model 1182

We have collected 10 000 events for each point for different DAC values from 1500 mV to 4000 mV in 100 mV steps using VME 8-channel LeCroy charge sensitive ADC model 1182, both for anodes of PMT's and outputs of preamplifiers placed inside Photon Calorimeter. With Luminosity Monitor DAQ we have collected 10 000 events for each point for corresponding DAC settings. The 1182 ADC has been AC coupled to subtract DC offset and 6 dB attenuators have been necessary ton fit the ADC scale for preamplifiers outputs. Pedestals have been subtracted from the DAQ data.

3 Results

All measurements have been performed in the HERA tunnel. Equipment (i.e. qVt, ADC, VME) have been tested and calibrated in the lab before measurement in the tunnel because the time of the accelerator break (access to the tunnel) has been limited.
Typical linearity curve is presented in Fig. 6 with setup I and qVt.

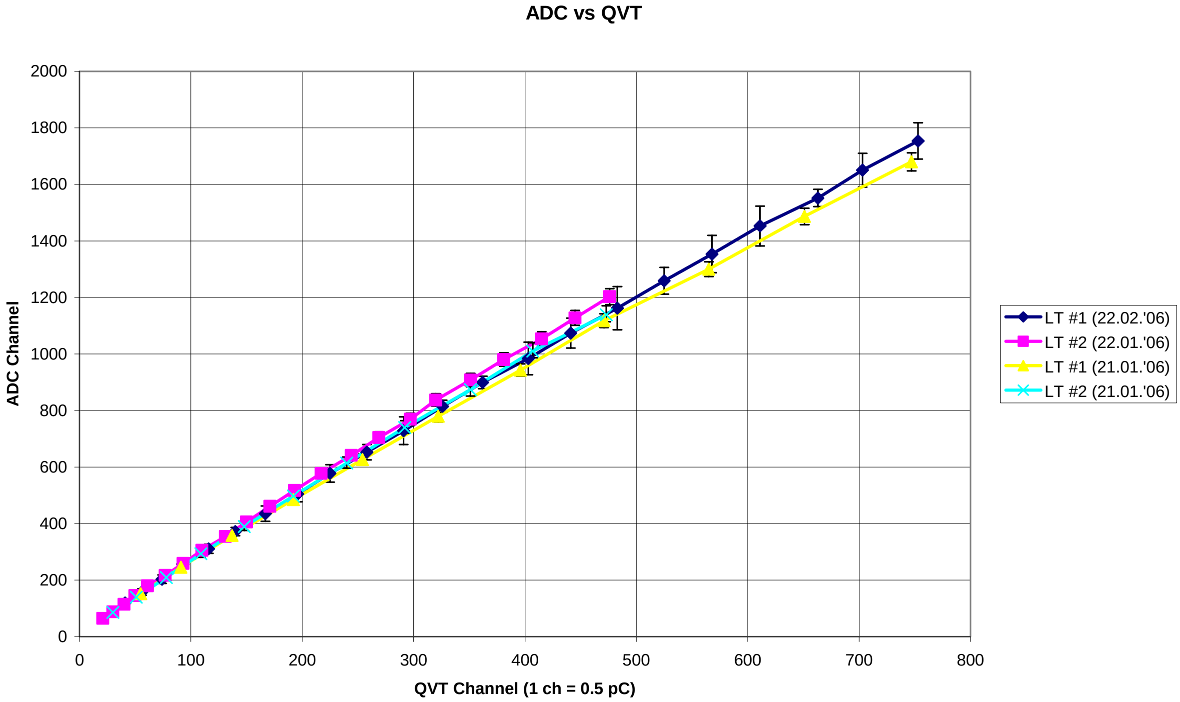

Fig.6. Linearity of two Photon Calorimeter readout electronics (except preamplifiers placed inside calorimeter).

ADC channels represent the DAQ output data and qVt channels correspond to the input signal charge.
To see the nonlinearity, it is necessary to show difference of the linearity curve from the straight line from point 0 to Full Scale for each channel (see Fig. 7.)

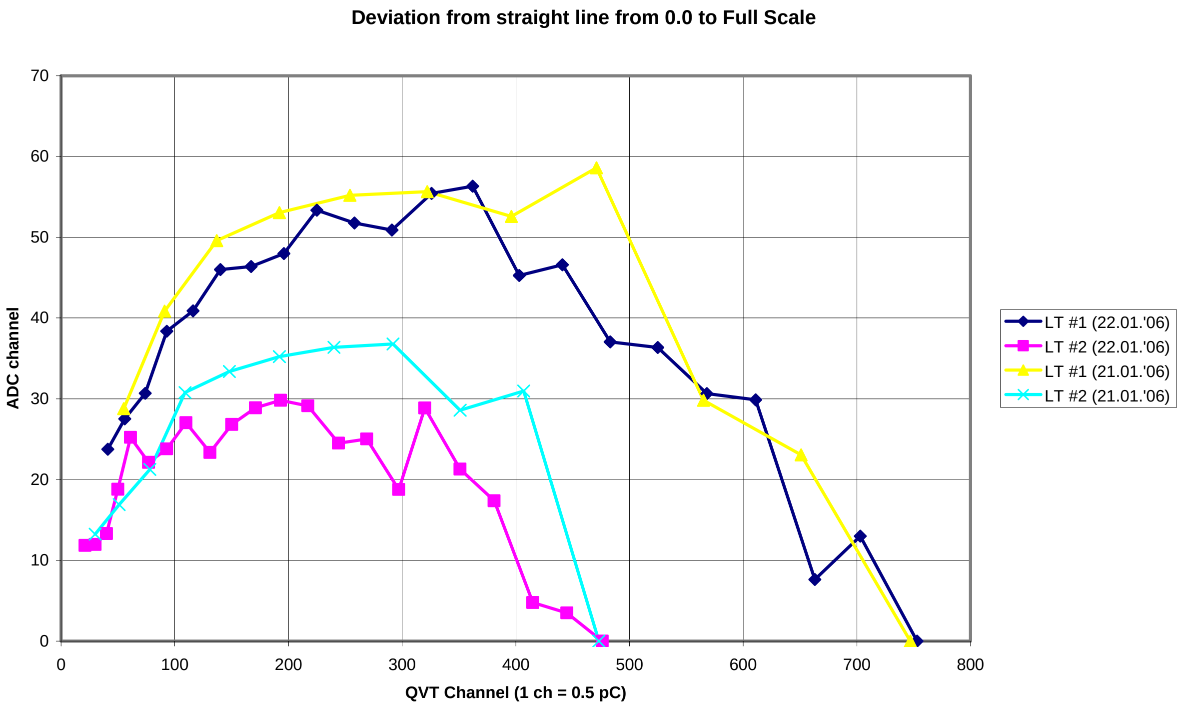

Fig. 7. Linearity deviation from the 0.0 to FS line for each readout channel

During measurements on 21& 22.01.2006, we have measure the input signals using the TDS520A scope. The results from scope are very similar to data taken with qVt. Comparison of our results with [1] is presented in Fig. 8.

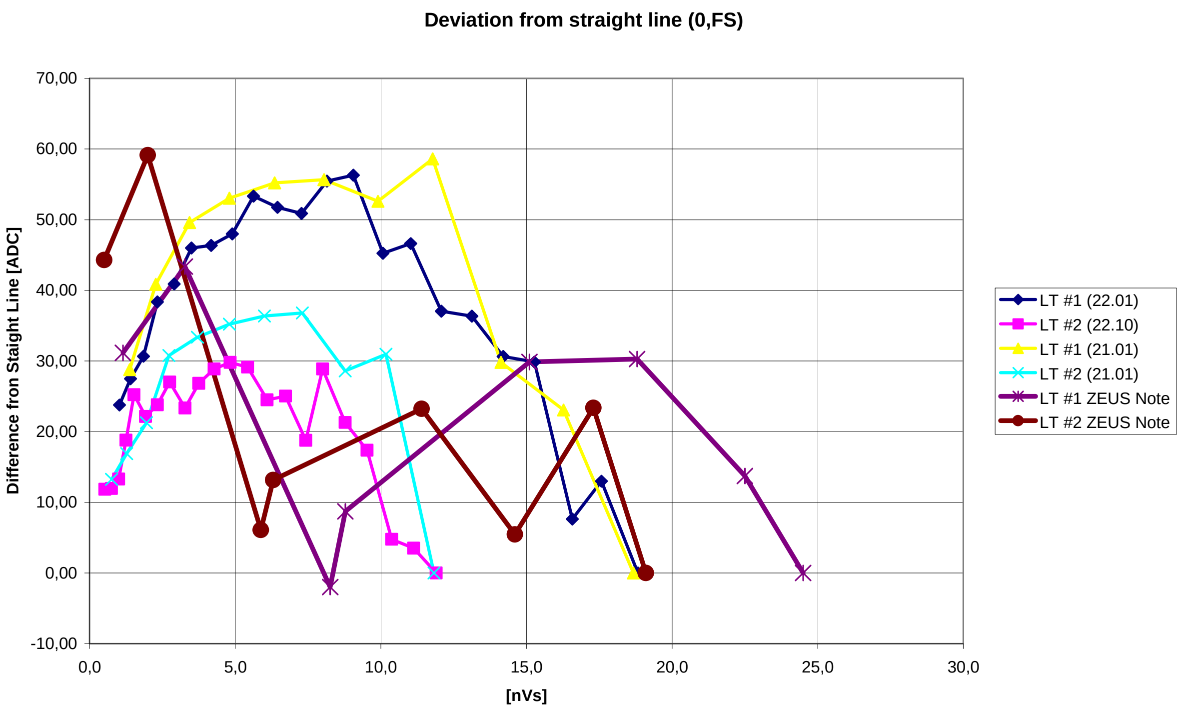

Fig. 8. Comparison of results taken 21 & 22.01.2006 with data presented in ZEUS Note.

The data presented in [1] have been taken using TDS520A scope under different conditions and that may be a reason that those measurements disagree. This forces us to repeat the measurements using setup II and III.

Plots presented in Fig. 9. and Fig. 10. summarized our linearity measurements.

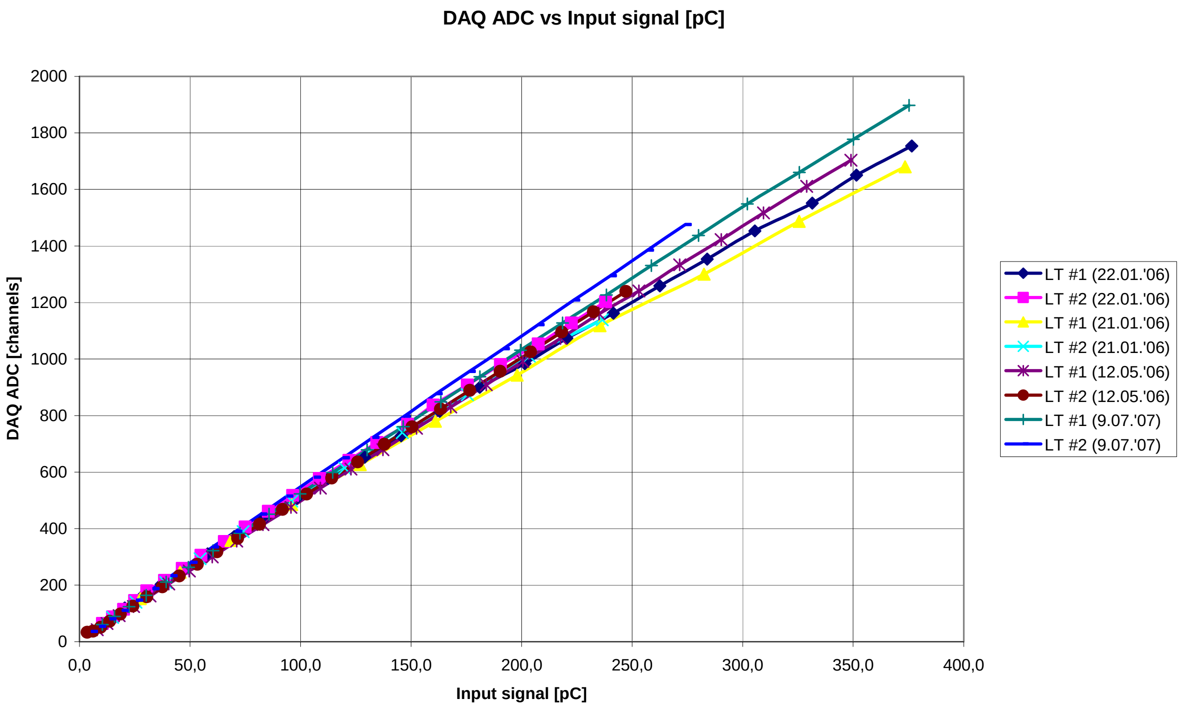

Fig. 9. DAQ ADC data versus input charge signal summarized for all measurements.

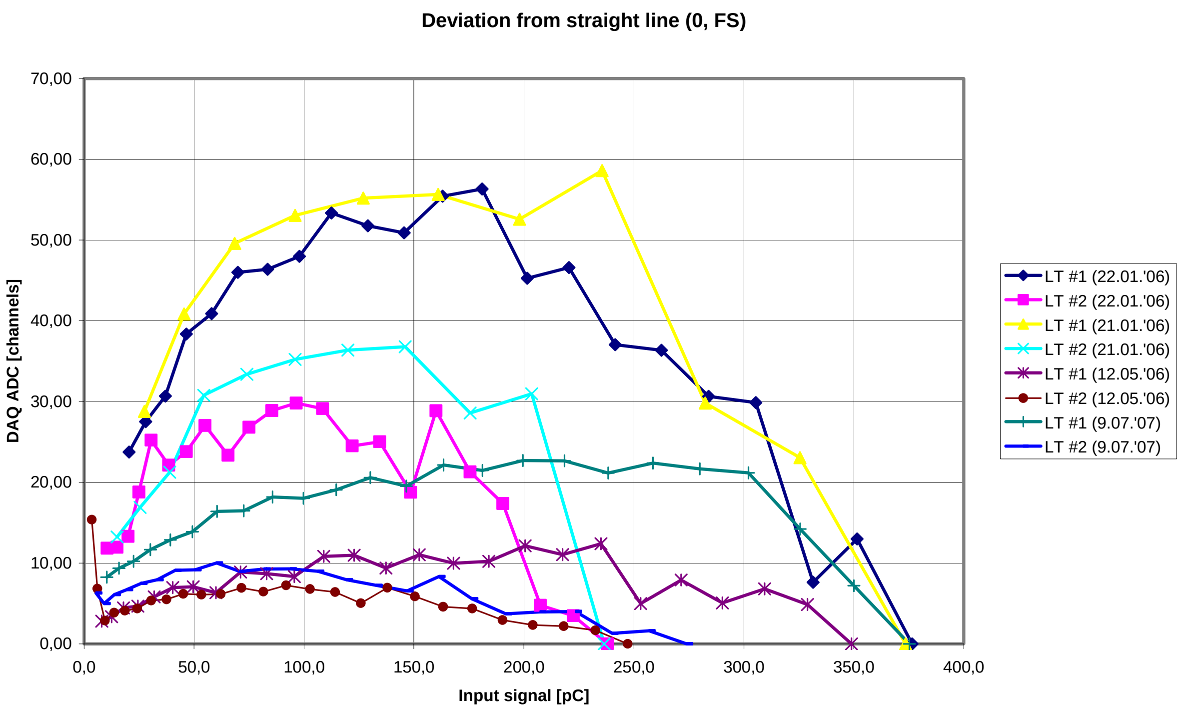

Fig. 10. Deviation from straight line from 0 to FS for DAQ ADC data versus input charge signal (without preamplifiers placed inside Photon Calorimeter).

After end of Luminosity Monitor operation, we have the possibility to measure the linearity of the readout electronic including the preamplifiers placed inside the Photon Calorimeter. We have to open calorimeter and measure the charge signal directly on the anodes of the PMT’s. Nonlinearity of both channels including preamplifiers is presented in Fig. 11.

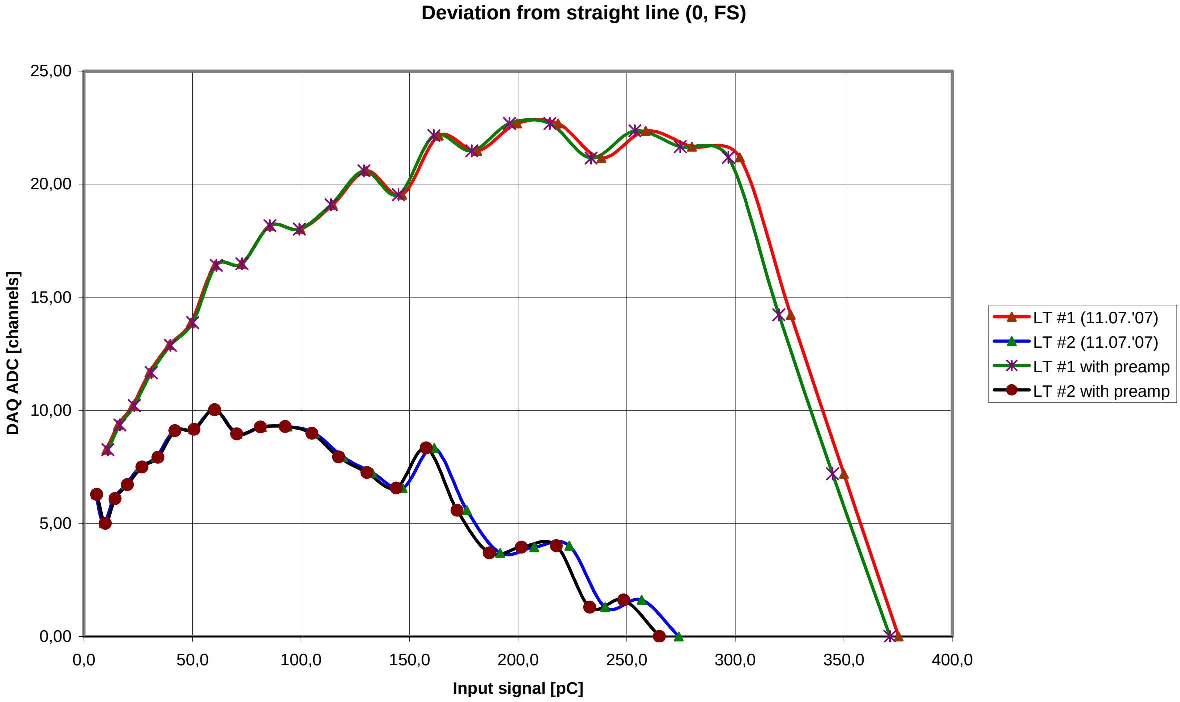

Fig. 11. Deviation from straight line from 0 to FS for DAQ ADC data versus input charge signal with and without preamplifiers placed inside Photon Calorimeter

4 Conclusions

Presented results, up to the last one, have been made only for frond-end, cable drivers and receivers, integrators and FADC. The linearity measurement of whole chain, including preamplifiers placed inside Photon Calorimeter, shows small contribution of the preamplifiers in total channel nonlinearity (Fig. 11) with order of ~1-2 channels ADC. This allows us to use the previous linearity curves to correct off-line data for particular time periods.
It is not clear, why the linearity curves changes with time. If we do not trust the measurements made with qVt (tested in lab before measurements) with manual readout (possible errors), the linearity of the readout channels can looked like in Fig. 12.

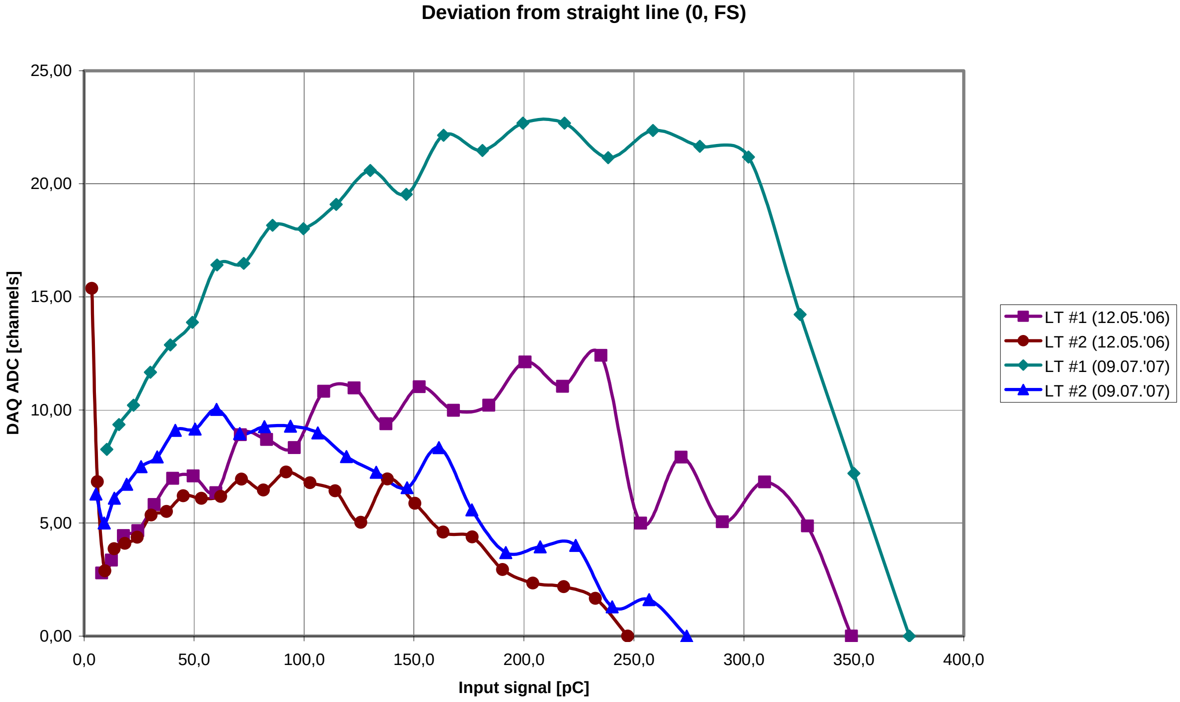

Fig. 12. Deviation from straight line from 0 to FS for DAQ ADC data versus input charge signal (without preamplifiers placed inside Photon Calorimeter) made with setup II.

The change of the linearity over 14 month is roughly 10 channels ADC for channel 1 (LT #1) and 3-4 channels ADC for channel 2 (LT #2). Such small changes can be induced by temperature changes and electromagnetic pickup noise in HERA tunnel.
Error bars are not shown on the plots because they are small.

References

1. P.Jurkiewicz, A.Kotarba, *Readout Electronics Linearity Measurement of the ZEUS Luminosity Photon Calorimeter*, ZEUS Note no. 05-026, 16.12.2005, DESY, Hamburg, Germany.