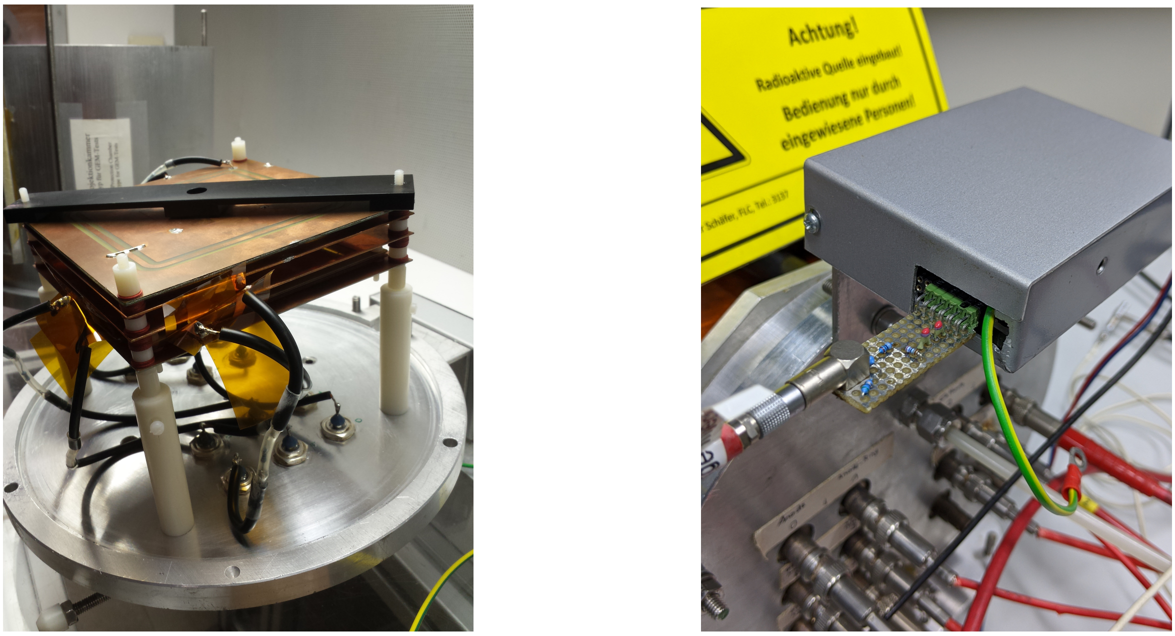
Gain measurement of double GEM stack

EDIT school

February 24, 2020

1 Introduction



(a) GEM Stack

(b) injector connected to preamplifier

Figure 1: Pictures of the prototype TPC.

In this experiment, the gas amplification of a double GEM stack should be determined. The prototype TPC for this experiment consists of a cylindrical field cage with a copper cathode and anode. A voltage of $-1.6\,\mathrm{kV}$ is applied to the cathode and distributed to the field cage through a resistor chain. The anode is kept on ground potential and serves as the charge collecting electrode. A

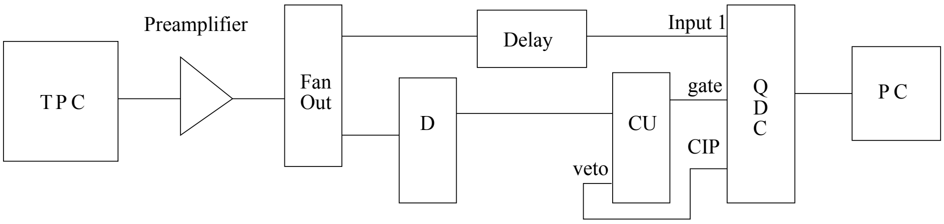


Figure 2: Sketch of the electronics; D = Discriminator, TU = Timing Unit, CU = Coincidence Unit, QDC = Charge to Digital Converter

double GEM stack is used as the amplification stage. Figure 1a shows a picture of the GEM stack.

On the cathode side a ^{55}Fe source is installed and injects $5.9\,\mathrm{keV}$ photons into the sensitive volume of the chamber. A gas mixture of 95% Ar and 5% CH_4 is used (so called P5 mixture). The averaged number of generated electrons per decay is 234, since the mean energy needed to produce an electron-ion pair in argon mixtures, as used in TPCs, is $W = 25.2\,\mathrm{eV}$. The amplification factor of the liberated electrons inside the double GEM stack should be determined here.

The anode signal is amplified in a HERMES preamplifier board with four Fujitsu MB43486, operated with $4.3\,\mathrm{V}$. Figure 1b show the box in which the preamplifier is installed. A charge to digital converter (QDC) is used to integrate the measured charge and digitize it for computer read out

2 First task: Trigger and readout setup

The first task is the installation of the trigger and readout setup. A sketch of the setup can be seen in figure 2 and pictures of all necessary devices can be found in the appendix. Table 1 in the appendix includes a short description of all necessary electronics modules. Switch on channel A of the HV unit and SLOWLY ramp it to $-1580\,\mathrm{V}$ (this should take one minute!). The signal from the preamplifier is duplicated in a fan out NIM unit. One output of the fan out will be used later as the input for the QDC. The QDC needs a gate signal as a reference when to start and stop the integration of the charge signal. The gate signal is created by feeding the preamplifier signal into a discriminator. The threshold of the discriminator should be set very low to detect small charge signals. The width of the signal should be as long as the pulse signal from the amplifier to detect the complete charge with the QDC. Figure 3b shows how the preamplifier and gate signal have to be arranged.

1. Use an oscilloscope to view the raw preamplifier signal (from the fan out) and the gate signal from the discriminator (use the second input from the bottom). Set the discriminator width and threshold according to the description above (a screwdriver is hanging at the side of the rack).

To prevent the QDC from integrating over several pulses, a veto signal is necessary. The output pin CIP (Conversion in Progress) of the QDC creates a signal every time the digitization process is initiated.

2. Use the CIP signal from the QDC as a veto signal for the gate. Use a coincidence unit to combine gate and veto. Check that the output signal width of the the coincidence unit has a similar length as the input signal.

3. The coincidence unit introduces a delay to the gate signal. Use a delay on top of the NIM crate to shift the preamplifier signal into the gate signal from the coincidence unit. When you are ready, connect the delayed preamplifier signal into channel 1 of the QDC.

3 Second task: Calibration of the Preamplifier and QDC

To determine the amplification of the double GEM stack we need to convert the QDC digitized counts into a measured charge. Therefore, we need to calibrate the QDC and preamplifier. A sketch of the calibration system is depicted in figure 4b. A pulse generator injects well defined charges into the system (a figure of the pulse setup can be found in the appendix figure 5). The charge injector is a coupling capacitor which converts the voltage pulses into a charge.

1. Disconnect the anode signal and connect the charge injector into the preamplifier (the injector and preamplifier should be aligned at the right hand side as seen in figure 1b).
2. Tell the tutor that you are ready to take calibration data.

To start the QDC:

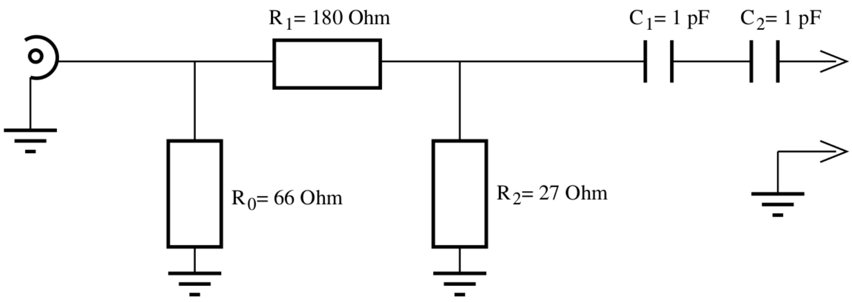
- log into the computer with username 'fe55'
- Open a terminal
- type 'telnet flctpcdaq01' with username 'tpc'
- change to directory 'qdc' ('cd qdc')
- start a measurement with 'qdc.exe -f FILENAME.qdc -n NUMBER_OF_FRAMES' (20000 frames are sufficient for testing)

To get the data:

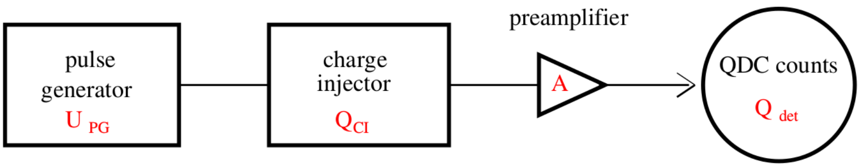
- open another terminal and change into the directory 'Q-analyser'
- use 'ftp flctpcdaq01' with username 'tpc'

(a) before delay (b) after delay

Figure 3: Pictures of oscilloscope with preamplifier signal in yellow and gate in blue



(a)



(b)

Figure 4: Sketch of 4a the charge injector device, and 4b of the charge injector assembly used for the calibration of the preamplifier.

- change directory with 'cd qdc'
- the data is transfered with 'get FILENAME'

To view the data

- open another terminal and change into the directory 'Q-analyser'
- execute './Q-analyser'
- open the file and view the resulting QDC distribution

2. Take a calibration curve with a couple of different voltages (range between 0.12 V and 0.35 V). The name of the files should follow the scheme: 'calibration_PULSERVOLTAGE.qdc' (e.g. calibration_0.25.qdc). 50000 frames are sufficient for calibration.

3. Analyze the calibration curve: Therefore, open a jupyter notebook on flctpclab1 from the 'Q-analyser' folder with 'jupyter-notebook'. Open the Calibration.ipynp notebook and follow the instructions there.

4 Third task: Gain Curve

Now, you can reconnect the anode output to the input of the preamplifier.

1. Take gain measurements for several different HV settings between -1550 V and -1600 V). Monitor the spectra with the Q-analyzer to verify that you are still within the QDC range. The naming scheme should be: 'EDIT_PULSERVOLTAGE.qdc' (e.g. EDIT_1580.qdc)

2. Analyze the gain measurements: Open the Analysis.ipynp jupyter notebook and follow the instructions there. The energy resolution would indicate a large gain is preferable. What are the restriction in a real life experiment?

3. Calculate the conversion factor for the QDC counts from the slope of the calibration curve. Insert the factor into the jupyter notebook to plot the effective gain $G_{\text{eff}} = \frac{Q_{\text{GEM}}}{Q_{\text{FE}}}$. C_{eff} of the injector is $65.2\,\text{fF}$. Can you think of any reasons why a fraction of the charge signal cannot reach the QDC?

A Appendix

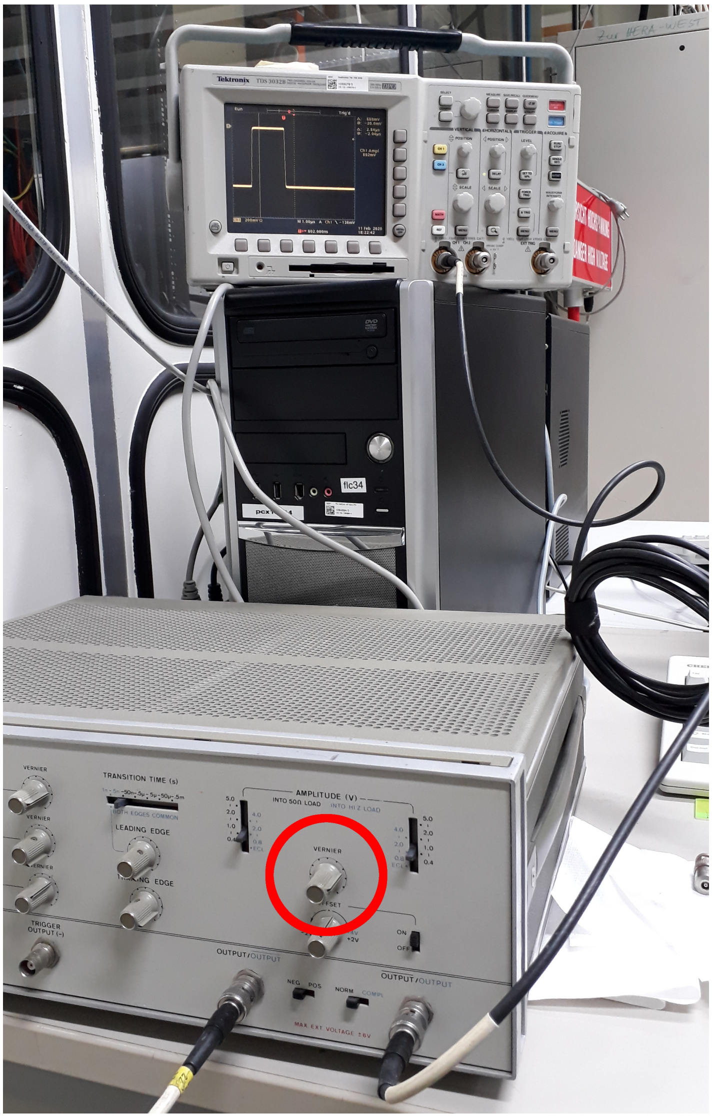
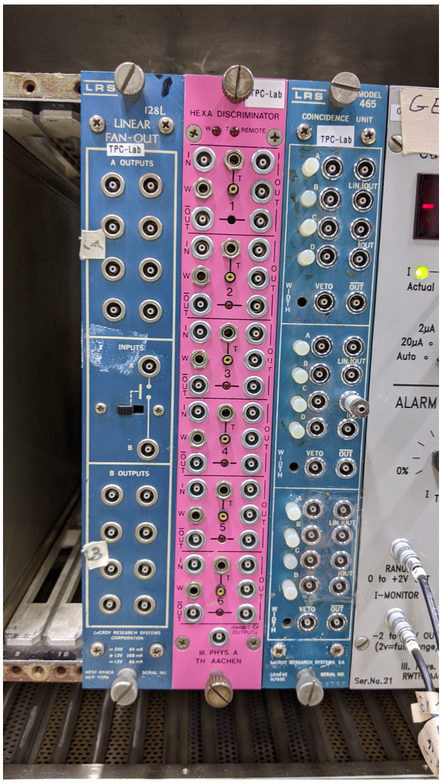


Figure 5: Sketch of the pulser setup. Turn the knob ‘vernier‘ on the pulser to modify the hight of the pulses (Don’t forget to switch it on). Use the oscilloscope to view the hight of the pulses (hight is noted on the right side of the display).

device	functionality
Discriminator	Sends out a rectangular pulse (logic true for NIM standard) if the input pulse is above a threshold. The threshold and width of the output pulse can be set screw
Fan out	The input signal is multiplied onto several outputs
Coincidence unit	Logic AND unit. Sends out a signal if all inputs high.

Table 1: Description of the NIM parts, which are used here



(a) trigger logic

(b) HV

(c) QDC

(d) delay

Figure 6: Necessary electronics parts

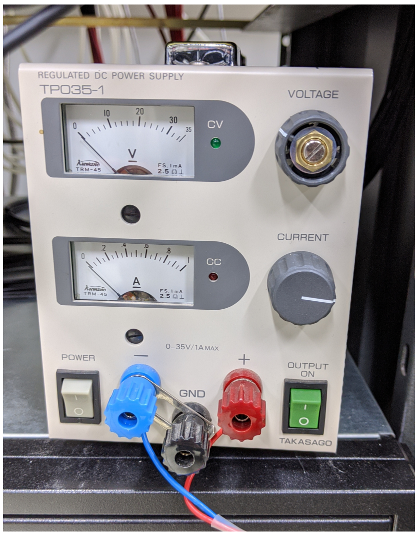


Figure 7: Don't forget to switch on the power for the preamplifier. Sometimes you need to switch it on several times until the voltage is applied

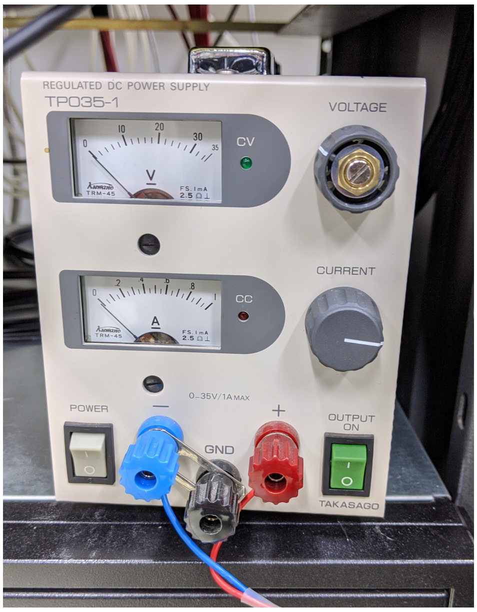


Figure 8: Don't forget to switch on the power for the preamplifier. Sometimes you need to switch it on several times until the voltage is applied