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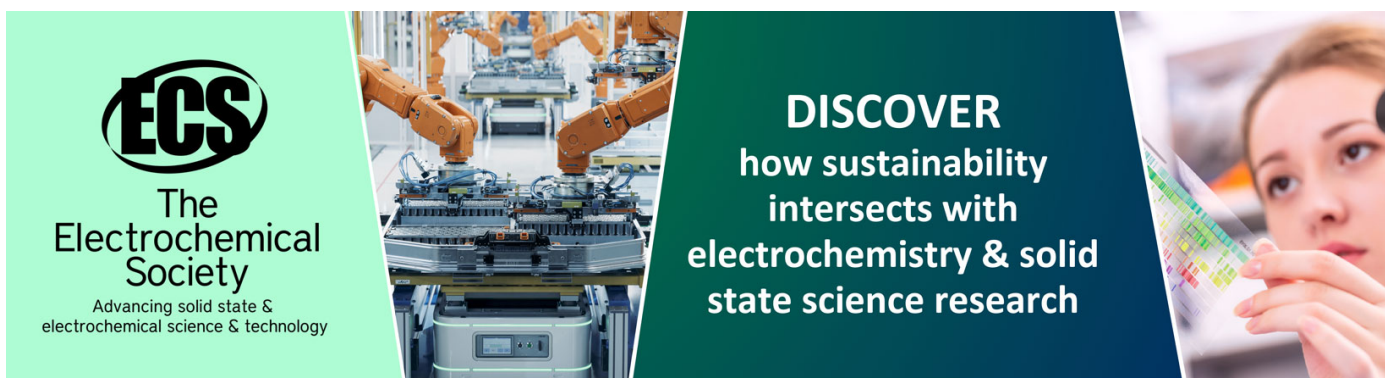
The triple-GEM detector for the Laser Polarimeter facility at VEPP4-M collider

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The triple-GEM detector for the Laser Polarimeter facility at VEPP4-M collider

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Abstract. The Laser Polarimeter is being developed at VEPP-4M collider for beam energy calibration by Resonant Depolarization technique. The essential part of this facility is a photon-tracking detector measuring coordinates of backscattered gammas.

1. The Laser Polarimeter facility

The VEPP4-M collider has a unique system for energy measurement based on Resonance Depolarization technique. The existing system is working well using the Touschek effect for measurement of polarization at the energies below 2 GeV [4]. Unfortunately, at higher energies the efficiency of the Touschek polarimeter is reduced [6]. For higher energies it was proposed to develop Laser polarimeter [5] which is based on the effect of up-down asymmetry of Compton backscattering of circularly polarized photons by vertically polarized electrons [7, 8].

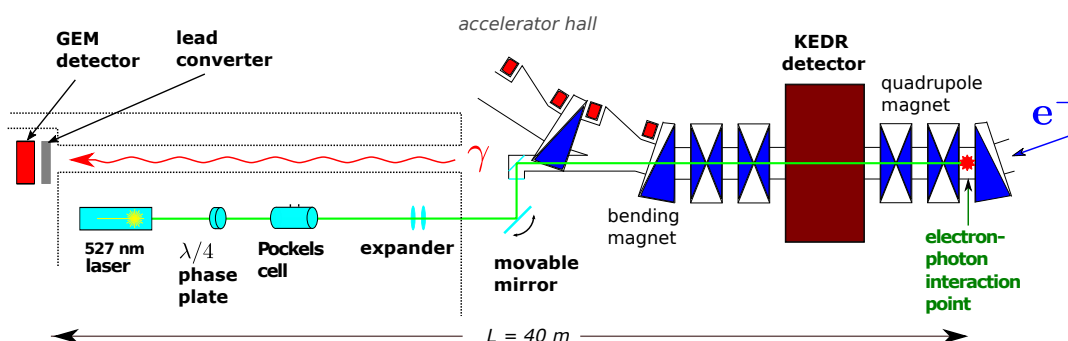


Figure 1. The Laser polarimeter layout at VEPP-4M.

The general view of the laser polarimeter at VEPP-4M is shown in Figure 1. The difference of an average vertical scattered angle for left and right circular polarization depends on the

beam polarization in this scheme. The first energy measurement using this scheme was done in 2017 [1] (fig. 2), while in this experiment for registering particles converted from back-scattered photons the tracking detector of the DEUTERON facility was used [2].

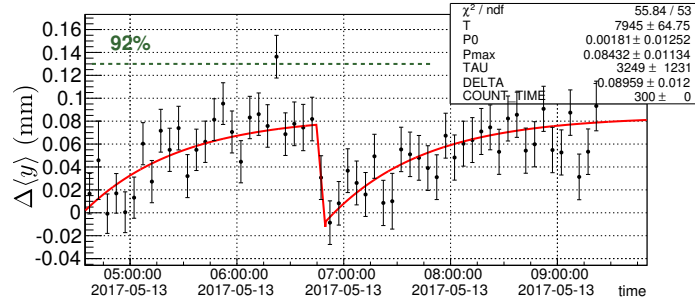


Figure 2. Radiative polarization process and depolarization jump observed at the energy of 4.1 GeV.

The spot on the lead converter where Compton photons hit, has a diameter of several millimetres. The trigger rate can be selected in the range of 1-4 kHz, while the amount of Compton photons in the flash is expected to be ~ 30 for every 10 mA current in the collider's ring. Thus, a specially designed triple-GEM coordinate detector with a pad readout was developed for the measurements of the position distribution of backscattered photons, with the requirements of having at least 1000 pads and a pad size being several times smaller than the spot.

A simulation was made to find out the optimal size of the readout pad and the spatial resolution required. The simulation showed that $2 \times 1 \text{ mm}^2$ pad is an optimal choice with enough resolution to detect the asymmetry effect [5].

2. The GEM Detector

The development of the detector's design was started in 2015 and during 2018 the detector was finally assembled. The detector has a sensitive area of $128 \times 40 \text{ mm}^2$ and consists of three cascades of gaseous electron multiplier (GEM) with the pad readout structure (fig. 3). The readout structure is a rectangular grid of 1120 pads, which are $2 \times 1 \text{ mm}^2$ sized in center and $4 \times 2 \text{ mm}^2$ on the edge, where bigger pads are used for a rough alignment of the detector. The gas mixture used is $\text{Ar}(75\%) - \text{CO}_2(25\%)$.

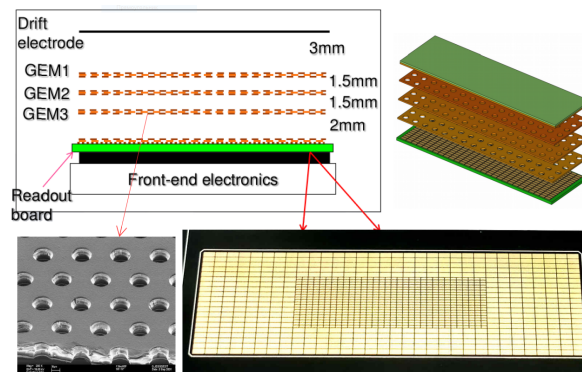


Figure 3. Schematic view of the detector's structure.

The detector electronics have modular design and encompass from several boards (fig. 4, 5):

- readout board with GEMs and pad readout structure;
- ten FE-boards with DMXG64 ASICs [3] and ADCs;
- CPU board (DE10-Nano) with FPGA/SoC and gigabit ethernet;
- trigger-polarity input board with LEMO connectors (NIM);
- Power supply board (low voltages for all boards);
- High Voltage board providing up to 4kV for the detector.

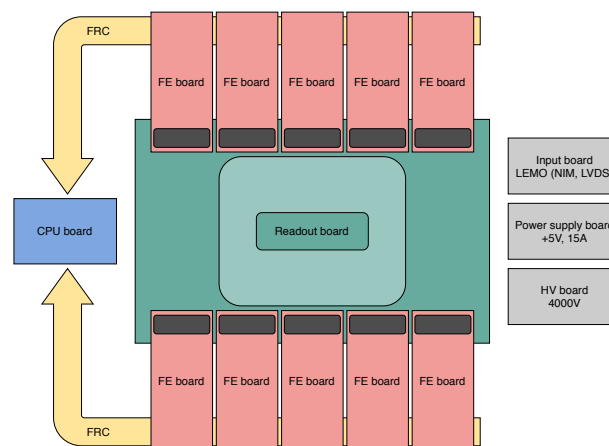


Figure 4. Overview of the detector electronics and data acquisition system.

FE-boards are inserted into FMC sockets on the readout board, to which the pads of readout structure are connected. FE-boards are grouped into pack of five for top and bottom regions. Each pack is connected in parallel via flat ribbon cable to 40-pin IDC connectors of the CPU board. The trigger-polarity input board is inserted into the Arduino socket of CPU board.

The modular design allows to replace some parts, for example the readout board can be replaced by the PCB with different readout structure without much efforts.



Figure 5. Bottom half of the detector assembled.

3. FE electronics

The most crucial requirements for the front-end electronics were: the dead time not exceeding $250\ \mu\text{s}$ (at 4kHz trigger rate) and total channels count no less than 1120.

Front-end electronics of the detector is based on the DMXG64 ASIC (64 channels, 100 frames of analog memory), twenty of these chips are required to cover 1120 channels in total. Thus it was divided into ten FE boards.

Each FE board (fig. 6) contains protection circuits against high voltage discharge, two DMXG64 ASICs (with dedicated 14bit ADC each) and Altera MAX10 FPGA to generate the sequence signals for the FE chips, readout and put the digitized data onto the parallel bus. Also, the FE board has a mini USB connector and FT230X USB-UART IC onboard, thus it can work standalone without CPU board. For the detector purposes only 1 frame of analog memory needs to be digitized, therefore even the ADC working in 1MSPS mode is enough to meet the timing requirement.

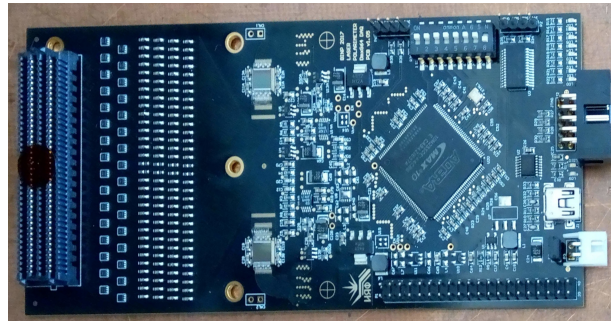


Figure 6. FE board.

The signal from the pads of the readout structure comes through the FMC connector passing by protection circuits into DMXG64 ASIC, after that digitized data from the dedicated ADCs go into FPGA and are transferred to the CPU board or PC by UART.

As the CPU board the Terasic DE10-Nano development kit is used (fig. 7). This kit features Cyclone V FPGA with the hardware dual-core ARM processor running Linux and many peripherals in compact enclosure.

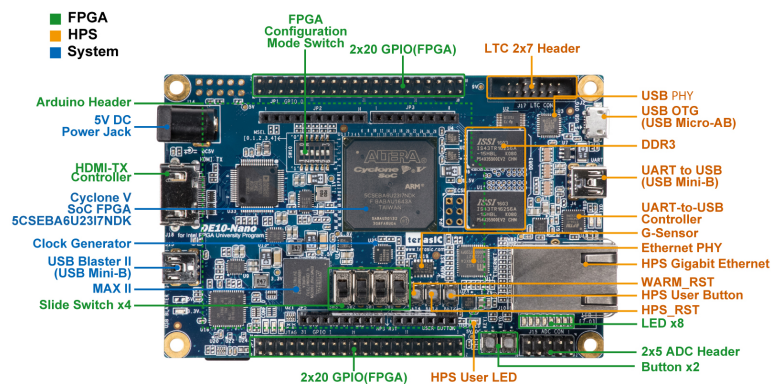


Figure 7. Terasic DE10-Nano development kit used as CPU board.

4. DMXG64 ASIC

The DMXG64 ASIC [3] was developed in Budker Institute of Nuclear Physics for various GEM-based detectors. It has 64 input channels, while each channel has low-noise charge sensitive amplifier and dedicated analog memory for 100 samples. Figure 8 shows the chip design from the engineering CAD software and the schematic of one channel.

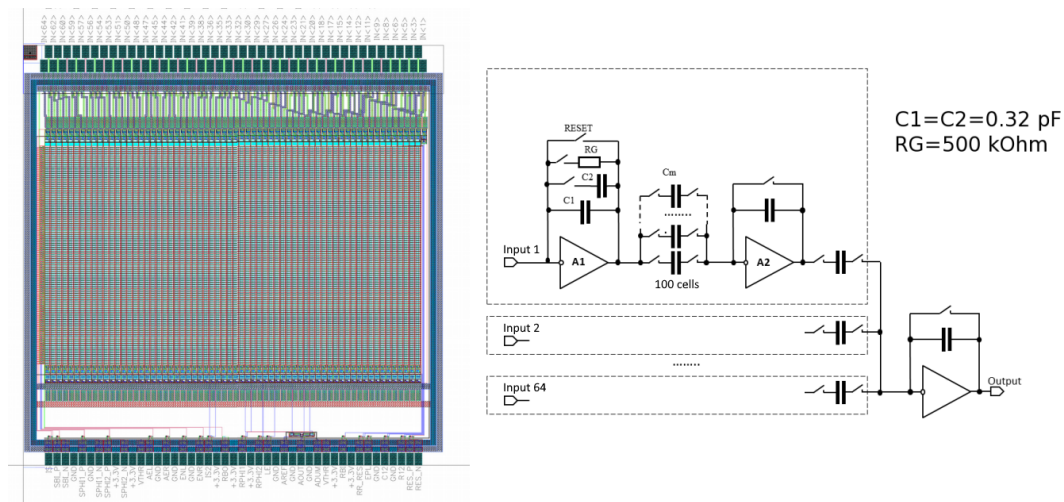


Figure 8. The overview of DMXG64 from CAD software (left) and schematic view of one of the 64 channels of DMXG64 (right).

The electronic calibration of the FE board channel was made and results complied to the previous study of the DMXG64 ASIC [3] (fig. 9).

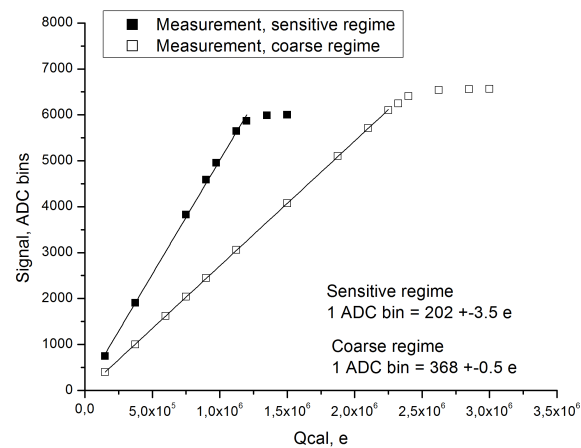


Figure 9. Electronic calibration results in two modes.

5. The measurements with Sr^{90}

Using a Sr^{90} radioactive source, measurements of the gas amplification factor were carried out. The results of this measurements are shown in Figure 11. An example of one of the events registered from one of the FE board is shown in Figure 10, as well as charge distribution in ADC bins. We see that the distribution conforms with the Landau law which is another proof that detector works as expected.

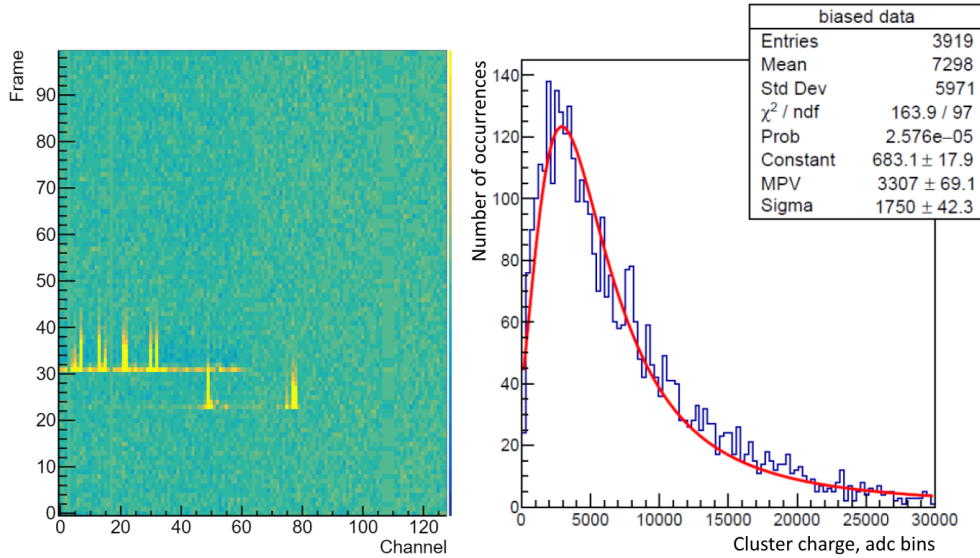


Figure 10. One of the events from the radioactive isotope registered in the laboratory (left) and the cluster charge distribution (right).

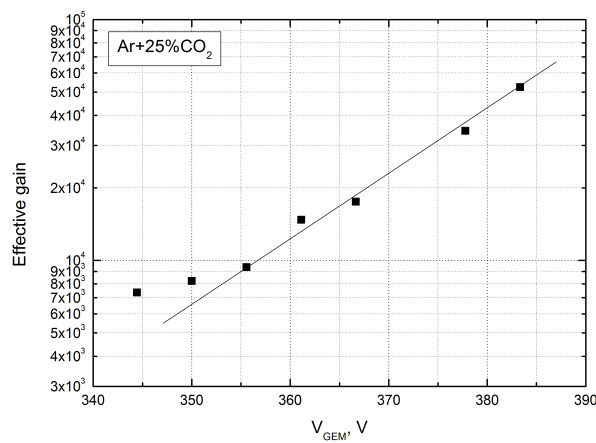


Figure 11. Amplification factor of the detector as a function of voltage for the single GEM.

6. Conclusion

The Laser Polarimeter facility is under active development. The principle of operation was proved, and the core components of the detector were manufactured and work well.

The detector performance is scheduled to be studied at the testbeam facility at VEPP4-M collider in November 2019.

Acknowledgments

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