The software and hardware for the ground testing of ALFA-ELECTRON space spectrometer

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Abstract. The complex for ground testing and space detector system calibration has been designed. The fast multilayer scintillation detector of the new telescope-spectrometer for the ALFA-ELECTRON space experiment is in ground testing mode now. The device will planned to install on the outer surface of the Russian Segment of the International Space Station. The basic scheme for the detector amplitude parameters measurement by use of specially designed hardware and software are described and the first prototype testing results are demonstrated.

1. Introduction

In the last 20 years a new class of atmospheric phenomena – the high-altitude electrical discharges (HED) formed above thunderclouds is intensively studied. It is supposed that a variety of observations for atmospheric, ionospheric and magnetospheric phenomena such as «red sprites», «blue jets», «elves», terrestrial gamma flashes and so on are related with them [1, 2].

From a large group of physical objects related to the HED, the acceleration process of high-energy electrons is very important. Direct detection of electron beams will not only confirm the existence of the electrons acceleration in the HED, but also to obtain data about the configuration, size and dynamics of the electric field in the upper atmosphere of the information on the energy spectra and temporal profiles of electron beams. One of the main functions of the ALFA-ELECTRON experiment [3] is electron beams detection from the HED.
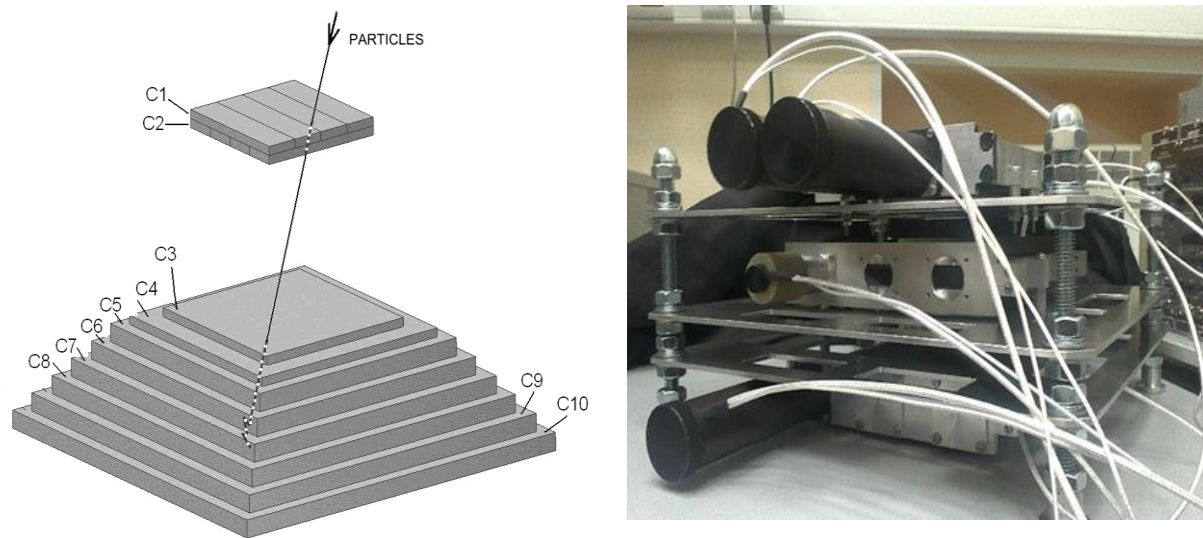
2. Physical scheme of spectrometer

The physical arrangement of the detector system is shown in the figure 1. The fast multilayer scintillation detector (MSD) consists of the set of C1 - C10 scintillation detectors. These scintillators have a high transparency and a minimum excitation time. It has been proposed for MSD to use the best (in terms of time and energy resolutions, amplitude characteristics, dimension and mass) Hamamatsu photomultipliers R5611-01A as photodetectors [3].

Structurally, the MSD [4] is composed of the upper detector system (UDS) and the scintillation calorimeter (SC). The UDS includes the detectors C1 and C2, which consists of four identical modules. The C1 detector module group is perpendicular to the C2 detector one. Each module is viewed separately by PMTs.

The SC is located at the distance of 100 mm from the UDS and consists of C3 - C10 detectors, each viewed by two separate PMTs.

Figure1. The ALFA-ELECTRON multilayer detector system physical scheme (left) and the experimental setup for one-layer detector system testing (right).

The detectors C1 and C2 are used as thin trigger aperture ones, the SC detectors (C3 - C10) are used as total absorption detectors where the particle absorbed will lose all its energy. So, the energy of electrons is measured mainly by the total energy of the particles absorbed in the SC detectors. The C10 detector is a veto detector for passing particles.

Digital controller unit [3] together with the pulse amplitude analysis one provides the separation of particles (electrons and protons) by analyzing the particle energy deposition in scintillation detectors when particles penetrate the layers of the MSD.

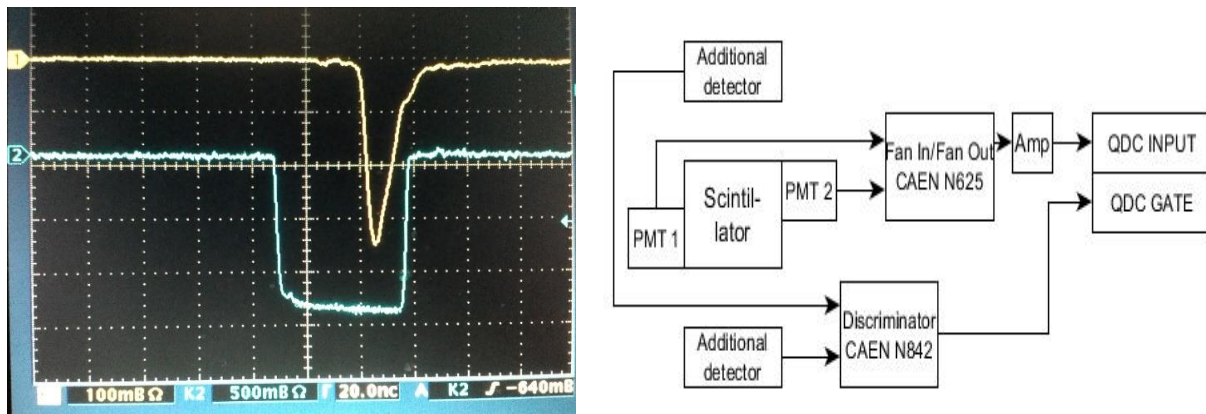## 3. Description of main possibilities of the hardware and software system

Currently in NRNU MEPhI the hardware and software for testing scintillation detectors system are under final tuning. This complex is based on industrial PC, NIM and VME electronic modules. Instrumentation and program support allowed to get the amplitude spectra in real time from 16 detector channels simultaneously also (with one QDC module – see the text below).

The hardware and software complex includes the following main features:
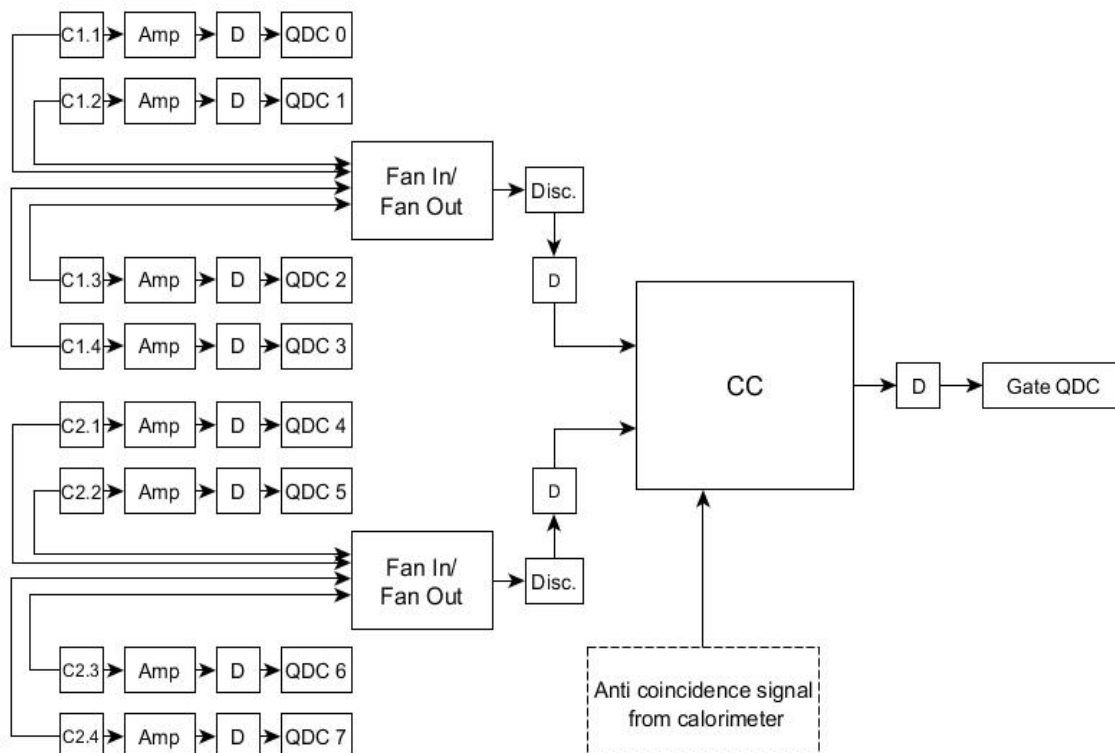
- provide an amplitude spectra measurement from cosmic radiation sources for a single detector channel (see figure 2) and for 8-16 ones (see figure 3);

- provide the possibility to exposure the thresholds and calculate the spectrum energy resolution (FWHM);

- provide a measurement of the dynamic range of the scintillation detectors;

- provide a verification of prototypes made front-end electronics for compliance with the stated parameters.

Figure 2 shows typical signals from the detector and the diagram for testing of one scintillation detector layer.

The diagram of amplitude characteristic measurement of spectrometer trigger detectors C1 and C2 is shown in the figure 3. Each of the detectors C1 and C2 has 4 channels of registration, because these detectors consist of four identical modules. C3 – C10 detectors has 8 channels. Thus, we have 16 channels in total.

Figure 2. Signals screenshot (left): typical signal from PMT (line#1), QDC Gate signal (line#2) and diagram of one-layer detector calibration (right).

Figure 3. The trigger UDS calibration setup block diagram.

As mentioned above, the C10 detector is a veto detector and close the coincidence scheme (CC) is connected with QDC Gate input.

For organization of measurement control signal (QDC input Gate) the output signals from C1 and C2 detectors are summing from all of the 4 PMTs (C1.1 – C1.4, C2.1 – C2.4) and output signals from C3-C10 detectors are summing from 2 PMTs (for one detector C3.1 – C3.2, for example). The CC allows to detect only those particles that are completely absorbed in the detectors. Calibrated delays (D) are connected to CC inputs for coincidence tuning of pulses.

In this installation we use standard NIM and CAEN analog modules (Fan In/Fan Out, Delay, Discriminators, Coincidence) and CAEN 16-channel QDC V965 controlled by PC program through crate controller V2718KIT VME-PCI Bridge (V27) and PCI Optical Link (A2818) with Optical Fibre5 m duplex (AY2705).
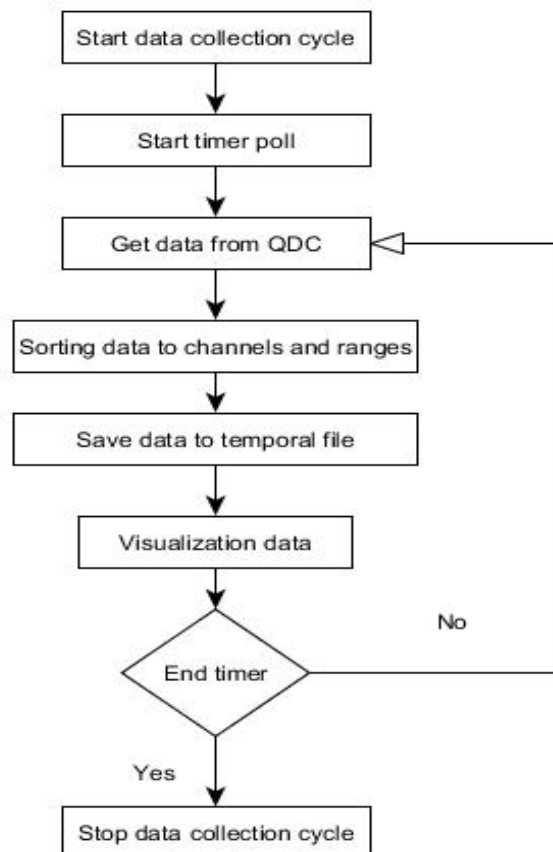
The software for this complex was developed by using C++ (in fact, IDE Qt Creator 5.3) and the main program runs under the Linux OS.

The basic functions of the main program are the following:

-set the parameters of the modules (see below);

-control the data collection process;

-provide a visualization of incoming data in real time;

-work with all of 16 channels in process of registration simultaneously;

-have the opportunity to save and open data files for the further work;

-have the opportunity to restore data if software or hardware will crash;

-provide the data preprocessing and result visualization.

Our control program allows to set the main electronic parameters: threshold, pedestal, sampling time. PC operator can calculate the statistic parameters of spectra (FWHM, maximum of peak, integral background) and paint spectra in different scales (logarithmic and linear) also.
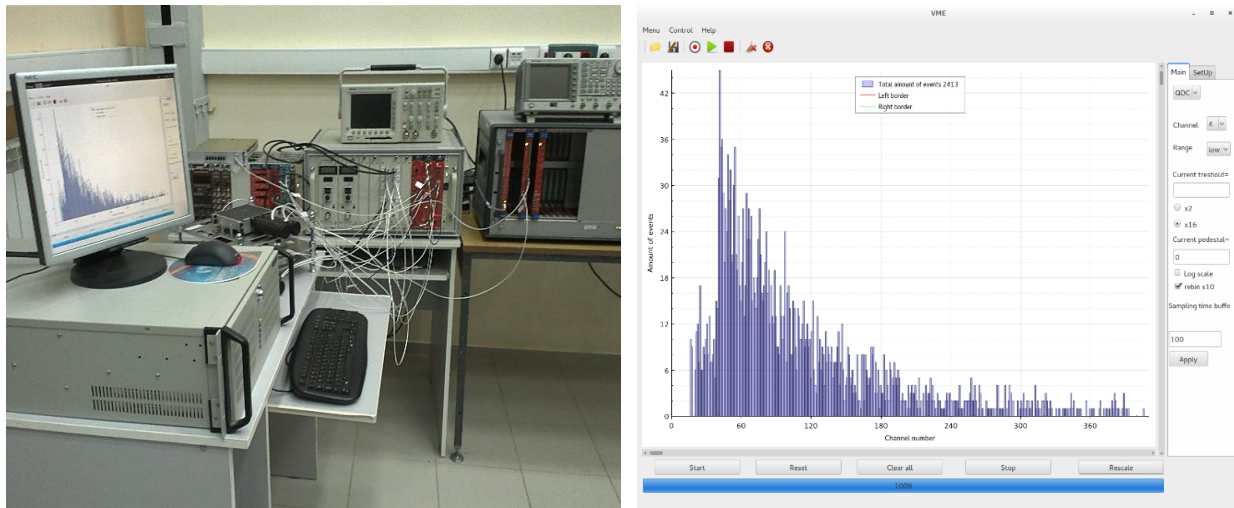
Using CAEN S.p.a. firm hardware and our original software allows to simplify a processes of ground calibration and detector systems testing for current and future space experiments.

Figure 4. Simplified block diagram of the data acquisition program.

Figure 4 shows the diagram of the data acquisition program implemented in the complex. After the data collection cycle initializing the timer runs and resets the QDC data block located in VME.

Then the data analysis and sorting of the values was obtained for one or more channels (if this option is enabled) and for two affordable QDC dynamic ranges. To prevent data loss (in unforeseen cases), the program provides the preservation of data in a temporary file. Then the visualization process of received data in a bar graph on the PC screen is realized. Figure 5 shows a common view of the ground testing complex and typical experimental spectrum as an example of the program working during detector testing on the cosmic rays fluxes at the ground level. This spectrum has a character form of Landau distribution, which corresponds to the amplitude distribution of cosmic muons at the Earth's surface.

Figure5. The ground testing complex (left) and PC operator window with typical spectrum (right).

4. Conclusion

Currently, in the NRNU MEPhI the new complex for ground testing and calibrations of space detector system have been designed. This complex based on standard NIM and VME electronic modules and is controlled by original PC program. Hardware and software complex was quickly adapted to the new space spectrometer, showed an enormous possibilities and opportunities and can be successfully used in other different ground scientific experiments with fast particle detectors.

Acknowledgements

References

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