The registration system of the coordinate-tracking setup on the drift chambers

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Abstract. The large-scale coordinate-tracking detector for registration of near-horizontal muon flux generated by ultra-high energy cosmic rays is being developed in MEPhI. Detector is based on the multiwire drift chambers from the neutrino experiment at the IHEP U-70 accelerator. Their key advantages are a large effective area (1.85 m²), good coordinate and angular resolution with a small number of measuring channels. Detector will be operated as a part of the experimental complex NEVOD, in particular, its registration system allows joint operation with Cherenkov water detector (CWD) and coordinate detector DECOR. Coordinate tracking unit on the drift chambers (CTUDC) is mounted on the opposite sides of CWD. It consists of two coordinate planes containing 8 drift chambers and represents a prototype of a full-size setup. Registration system of the CTUDC is based on the E-MISS electronics developed in IHEP, its principle of operation is presented.

1. Introduction

The aim of the large-scale coordinate-tracking detector is solving the problem of the excess of muon bundles that increases with the energy of the primary cosmic rays [1, 2], what can be caused by both cosmo- or nuclear-physical reasons [3]. The only characteristics that responds differently to changes in the composition of cosmic rays and the inclusion of new physical processes, but has not been investigated to the present time, is the energy of the muon component of extensive air showers [3]. Such studies are performed at the experimental complex NEVOD-DECOR [4]; however, the coordinate detector DECOR does not cover the entire aperture of the water Cherenkov detector and does not exclude the possibility of passing of several muons between the individual supermodules of the detector. Besides, the size of its cells limits the possibility of separating two or more particles at small distances (less than 3 cm). The new coordinate-tracking detector [5] based on drift chambers will increase the coverage of the side aperture of the Cherenkov water detector (CWD) NEVOD and significantly improve the resolution of close tracks.

The detector is based on the multiwire drift chambers from the neutrino experiment at the IHEP U70 accelerator [6]. Overall sizes of the chambers are 4000×508×112 mm³. Sensitive area is 1.85 m² that is 91% of the chamber area. The chamber represents an aluminum box with ends limited by plexiglas plugs, to which wires, gas inlets and high voltage connectors are mounted. The drift chamber
is filled with a gas mixture of 94% Ar and 6% CO₂. A uniform electric field is formed by field-forming wires with a pitch of 5 mm, the potential on them varies linearly from 0 to 12 kV. The drift chamber has four signal wires alternately shifted by ± 0.75 mm in the drift direction relative to the centre of the chamber; such configuration allows to reconstruct the projection of the track on the plane perpendicular to the wires. Thus, for the reconstruction of tracks in space at least two non-parallel drift chambers are required. Spatial accuracy of the chamber is 1 mm, the angular resolution is about 0.03 rad, two close tracks can be separated at a distance of 3 mm.

The signals from the wires are processed by an on-board amplifier-shaper that forms 75 ns pulses (depending on the signal length) in the LVDS levels.

Figure 1. Arrangement of the CTUDC planes relative to the DECOR and CWD.

2. CTUDC
Coordinate-tracking unit based on drift chambers (CTUDC) consists of two vertical coordinate planes installed at the different sides of the CWD in the short galleries of the third floor of the NEVOD building, one floor above the DECOR supermodules (figure 1). Such location allows the registration of near horizontal tracks as by CTUDC (triggered by CWD) so by joint operation with DECOR, that will significantly increase the range of muon track zenith angles from 85–95° to 80–100°.

Each plane consists of 8 drift chambers installed in two rows, overlapped by 30 cm to exclude dead zones in the chamber ends; it causes a 4° angle between the planes and CWD wall. The effective area of the plane is 14.8 m², area of two DECOR supermodules located a floor below is 17.5 m², so the total area of coordinate detectors for registration of near-horizontal particles coming along the CWD almost doubles. One of the main goals of this setup is to examine conditions of the joint operation with CWD and DECOR.

3. Registration system
CTUDC is designed for joint operation with the triggering system of the experimental complex NEVOD (NEVOD TS) that binds registration systems of CWD, DECOR, calibration telescope system (CTS) and array of neutron detectors PRISMA. Triggering system has a rather fast data handling: the period between the passage of a particle through the working volume of CWD and the trigger formation is about 500 ns. On the other hand, the maximum drift time of the electrons in the drift chamber is 6 µs, so registration system and DAQ of CTUDC cannot be directly integrated into the NEVOD TS and should be implemented separately with possibility of off-line interconnection between the NEVOD and CTUDC data.
Registration system of CTUDC is based on the E-MISS electronics (a block diagram is shown in figure 2) developed for accelerator experiments in IHEP. It includes a 128-channel time-to-digital converter EM-4, main crate controller EM-1 and standalone controller EM-8.

Primary processing of signals from sense wires of drift chamber is carried out by the 4-channel shaper-amplifier AMR-4 (mounted on the end face of the DC) with a single adjustable threshold for all channels. It forms 75 ns LVDS pulses that pass through several commutation blocks to a TDC EM-4. There are 64 channels in 16 chambers, it lefts a half of TDC channels unused so after the expansion of the drift chamber setup to the TREK [6] CTUDC channels can be included into its full registration system.

The EM-4 represents four 32-channel independent TDCs based on a FPGA ACEX with $32 \times 1024$ words memory in each. TDC has $8 \mu$s match window with a 10-bit width time measurement, that corresponds to 7.8125 ns LSB. Such discretization is acceptable taking into account that spatial accuracy of the drift chamber is about $\sim 1$ mm, that corresponds to 24 ns drift time.

Trigger signal of the NEVOD TS acts as the time stamp for TDC, it is produced with implementation of any trigger condition of CWD and DECOR (configured separately for each detector). All delays in the triggering system are finely tuned, so a time between the passage of the first particle in the event and the all-system trigger does not depend on the type of completed trigger condition and is approximately 225 ns, it takes 100 ns for a cable delays and a hardware jitters and 125 ns for the triggering system. All signals from the drift chambers should be received by the TDC before the arrival of the NEVOD trigger, so the delay of the trigger is necessary. For this purpose, a special block for VME crate was developed, it combines a galvanic isolation by rapid optocoupler, TTL to
NIM converter (MC10124P) and 8 µs delay (SN74123N). Reception of the trigger signal is carried out by EM-1 controller that distributes it via MISS bus to EM-4 TDCs.

After the generation of the trigger signal in the NEVOD TS, the system transmits all information about inner triggers to the NEVOD central computer that starts (via Ethernet) to gather all amplitude information from the CWD and a configuration of triggered DECOR streamer tubes. Simultaneously the NEVOD central computer sends a network packet to CTUDC that contains main information about the event: the number and time of the event, types of CWD and DECOR inner trigger signals. The network packet is started with a 4-byte sequence at which the CTUDC central computer determines the type of the received packet, decodes it and starts to collect information from the E-MISS system.

Readout from the E-MISS system can be performed via Q-BUS from EM-1 or via USB from EM-8 that significantly differ. The EM-1 is designed for a full bus control; it is the only module that can be handled from the computer. It has three trigger inputs and three controllable NIM outputs, that are used for EM-8 control. The memory of module is two 1K 16-bit blocks (one for address and one for data) that is insufficient to read full memory of the EM-4 (4×32×1024 bits) so readout of a TDCs is performed for each event. This is acceptable for low rate measurements, but it is impossible to measure DC noise in such mode.

The EM-4 does not have continuous mode of operation for noise measurements, so an oscillator based on two monostable multivibrators is used for production of a trigger with 100 kHz rate. Each trigger opens 8 µs match window every 10 µs. EM-1 controller is not able to handle such high rates unlike standalone controller EM-8 that has memory for 16M of 32-bit words and can accumulate data. On the other hand, EM-8 cannot be controlled directly via USB and is not able to perform readout and data transmission independently, so three NIM outputs of EM-1 are used to control this module. Another feature of joint operation of two controllers is the possibility to reduce dead time (during transmission of data to computer) due to their alternate readout from the TDC. Full-sized setup TREK will consist of 264 drift chambers and it will produce a high load for registration system (including 10 EM-4 modules), especially for noise measurements, so an upgrade for the EM-8 is in progress.

Central computer of CTUDC gathers information from the E-MISS, and after the primary data processing the software forms the event. Later these events will be off-line joined with the events saved at the NEVOD central computer by means of time stamps and event numbers.

4. Conclusion
The unique coordinate-tracking detector CTUDC based on drift chambers from IHEP neutrino experiment is developed in MEPhI. Detector has a complex registration system that allows its joint operation with other systems of the experimental complex NEVOD. Registration system is based on the E-MISS electronics from IHEP that fulfills the requirements of the experiment. Currently the detector is on the calibration stage. It has been already cross-calibrated with the coordinate detector DECOR and operates jointly with the Cherenkov water detector.

Acknowledgments
This work was performed at the Unique Scientific Facility “Experimental complex NEVOD” within the framework of the Center Fundamental Research and Particle Physics supported by MEPhI Academic Excellence Project (contract 02.a03.21.0005 of 27.08.2013). The work is also supported by the grant of the Russian Foundation for Basic Research (project 13-02-12207-ofi-m-2013).

This work is supported by the grant of the Russian Foundation for Basic Research (project 13-02-12207-ofi-m-2013) and was performed at the Unique Scientific Facility “Experimental complex NEVOD” within the framework of the Centre of Fundamental Research and Particle Physics supported by the MEPhI Academic Excellence Program (contract № 02.a03.21.0005).

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