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The coordinate-tracking detector based on the drift chambers

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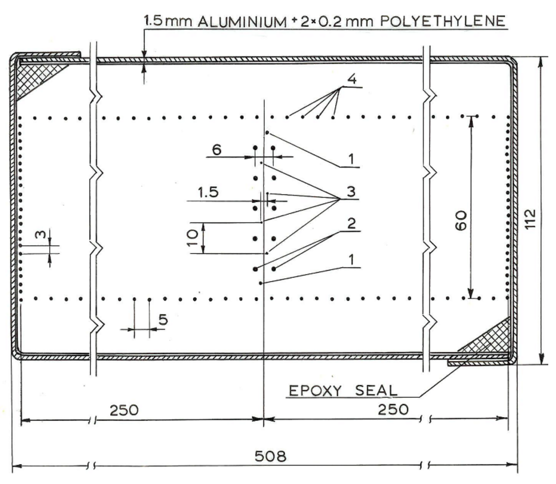
The large-scale coordinate-tracking detector TREK for registration of near-horizontal muon flux generated by ultrahigh energy cosmic rays is being developed in MEPhI. Detector is based on the multiwire drift chambers from the neutrino experiment at the IHEP U-70 accelerator. Their key advantages are a large effective area (1.85 m^2), 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, jointly with Cherenkov water detector (CWD) with volume of 2000 cubic meters and coordinate detector DECOR. The prototype of this large detector (CTUDC) representing two coordinate planes of 8 drift chambers in each has been developed and has been mounted on the opposite sides of the CWD. It has the same principle of joint operation with NEVOD-DECOR triggering system and the same drift chambers alignment, so main features of the detector TREK will be examined. Results of a cross-calibration of the CTUDC and coordinate-tracking detector DECOR and a joint work with NEVOD-DECOR complex are presented.

IHEP Drift Chamber

IHEP drift chamber was developed specially for the neutrino experiment. The specific features of such experiments (low event rate, moderate requirements for spatial resolution) allow the use of drift chambers with a large drift gap for detection of particle tracks.

Overall size of the chamber is 4000x508x112 mm^3. Sensitive area is 3.7x0.5 m^2 that is 91% of the side chamber area. There are four sense wires alternatively shifted by ± 0.75 mm parallel to the drift direction in the middle of the chamber to solve right-left ambiguity. There are two guard wires to remove the edge effect. The sense and guard wires are surrounded by the cathode wires. The field shaping wires are soldered on the printed circuit together with a high voltage divider which ensures a uniform potential distribution from 0 to 12 kV. Due to a nice uniformity of the electric field inside the chamber, electron drift velocity can be assumed to be constant and we can use a linear relation between drift time and coordinate. Maximum drift time is about **6 µs** (corresponding drift velocity is 42 mm per µs).

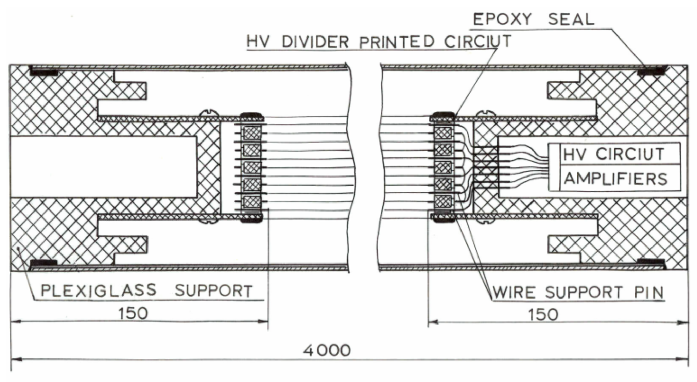
The chamber gas volume is limited by the 1.5 mm thick aluminium alloy case which serves simultaneously as an electric screen and the chamber frame. The electric insulation is provided by two layers of 0.2 mm thick polyethylene film glued on the internal surface of the case.



Drift chamber cross section in plane perpendicular to sense wires,
1 - guard wires; 2 - cathode wires;
3 - sense wires;
4 - field shaping wires

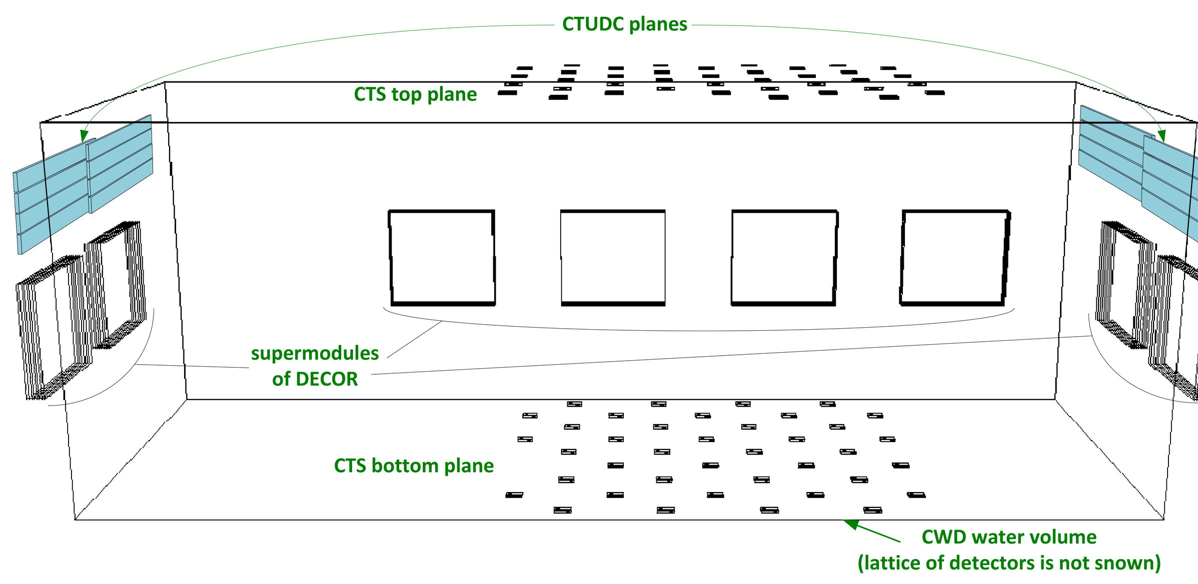
Drift chamber wires

Wire	Material	Diameter, µm	Tension, gf	Potential, kV
Signal	Stainless steel	64	400	+2.2 (+14.2)
Guard	Stainless steel	200	1800	+2.2 (+14.2)
Cathode	Stainless steel	200	1800	0 (+12.0)
Field shaping	Cu-Be	200	700 (900)	-12→0 (0→12)

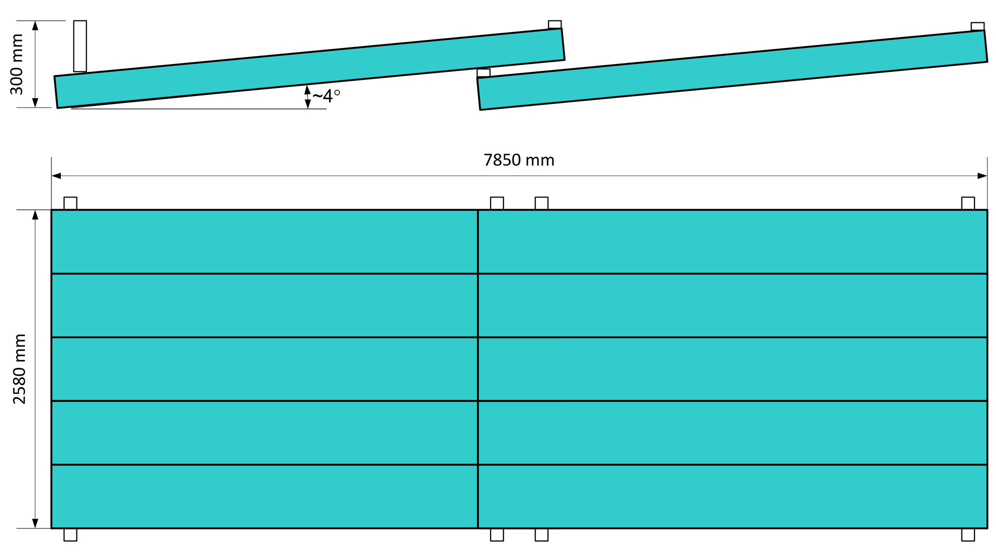


The chamber is filled with a gas mixture **Ar (94%) - CO_2 (6%)** at a small overpressure about of 10-20 mbar. The chamber gas volume is 210 litres. Signal wires provide current pulses through capacitors to shaper amplifier UD-4 (its mean threshold is **0.8 mA**). Amplifier provides 70 ns signals, their length limits the two-track resolution by **4 mm**. Spatial accuracy of IHEP drift chamber is **0.6 mm**, angular resolution is about **0.03** rad. Right-left ambiguity is solved in **98%** of events. Efficiency of a single wire is 98±2%.

CTUDC

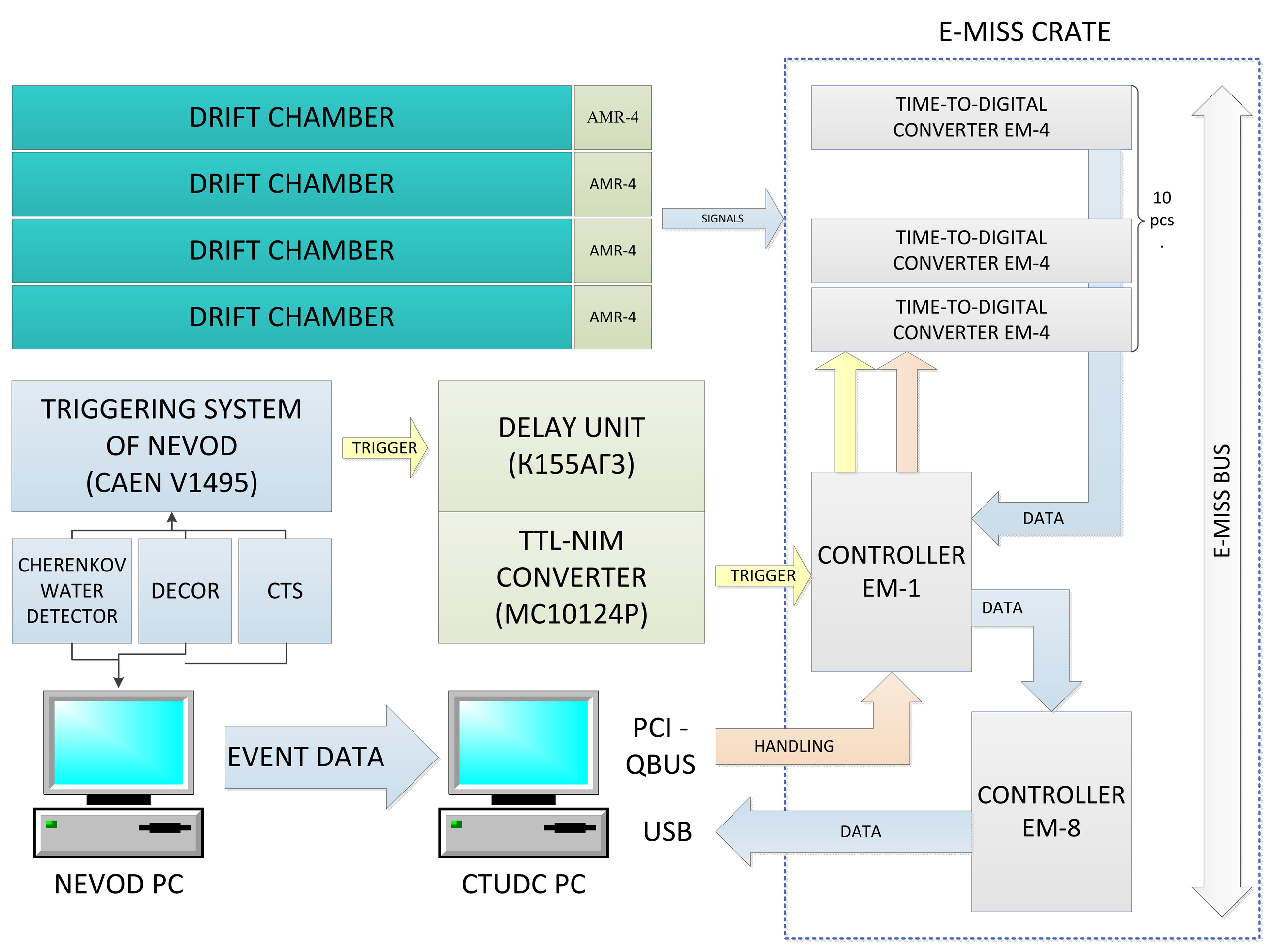


Coordinate-tracking installation of drift chambers (CTUDC) consists of two vertical coordinate planes installed at the opposite sides of the CWD in the short galleries of the third floor of the NEVOD building (on the floor above DECOR supermodules). Such location allows the registration of near horizontal tracks as by own CTUDC data so by joint data with DECOR, that will significantly extend the range of muon track zenith angles from 85-95° to 80-100°.

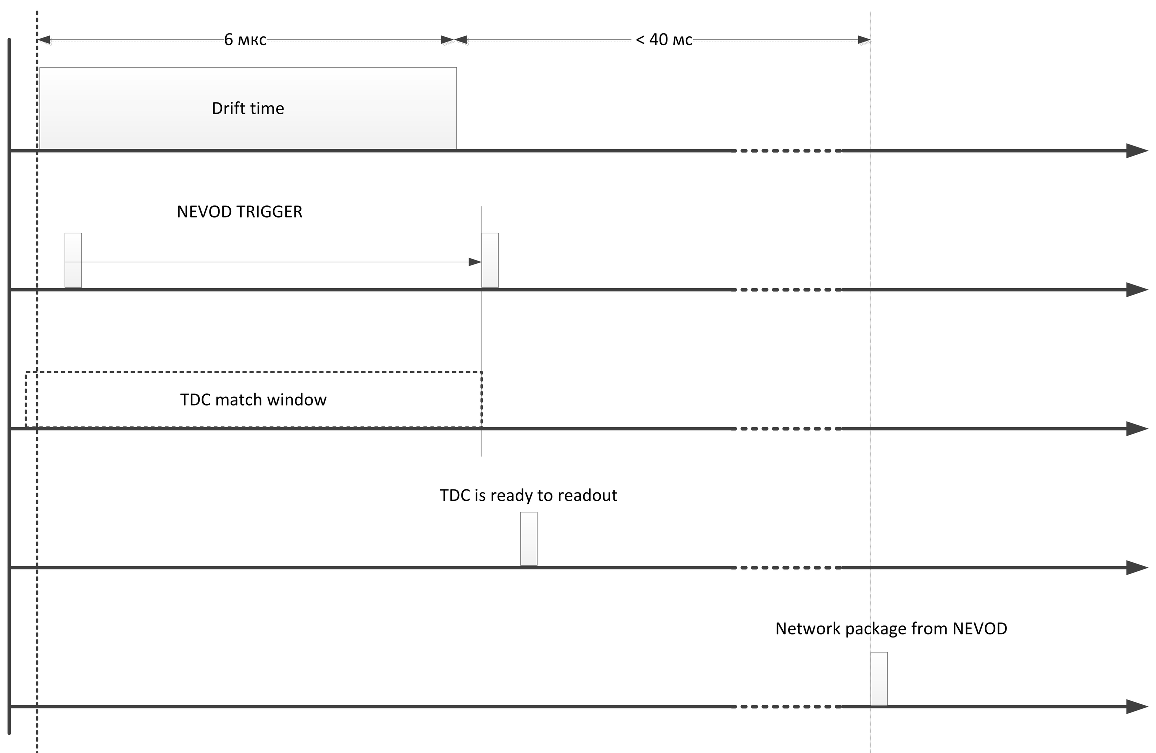


The plane consists of 8 drift chambers installed in two rows, overlapped by 30 cm to exclude dead zone in the chamber ends, it causes a 4° angle between planes and CWD wall. The effective area of the plane is 14.8 m^2, area of two DECOR supermodules located a stage below is 17.5 m^2 so the total area of coordinate detectors for registration of nearhorizontal particles coming along the CWD almost doubles. One of the main goals of this setup is to examine conditions of joint operation with CWD and DECOR.

Registration system



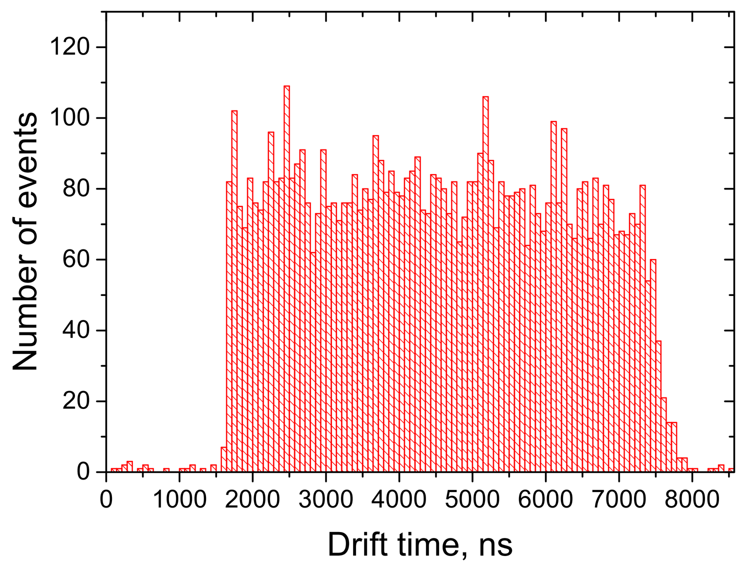
Coordinate-tracking detector CTUDC is designed for joint operation with complex NEVOD triggering system (TS). Triggering system has a rather fast data handling: the period between the passage of a particle through the working volume of CWD and the output of the trigger is about 500 ns. On the other side, 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 NEVOD TS and should be implemented separately. Primary processing of signals from sense wires of drift chambers 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 128-ch time-to-digital converter EM-4. There are 64 channels in 16 chambers and single TDC can handle all of them, so after the expansion of the drift chamber setup to the TREK, CTUDC channels can be included into its registration system. Trigger signal of NEVOD TS acts as the time mark for TDC, it is produced with implementation of any trigger condition of CWD or DECOR (configured separately for each detector).

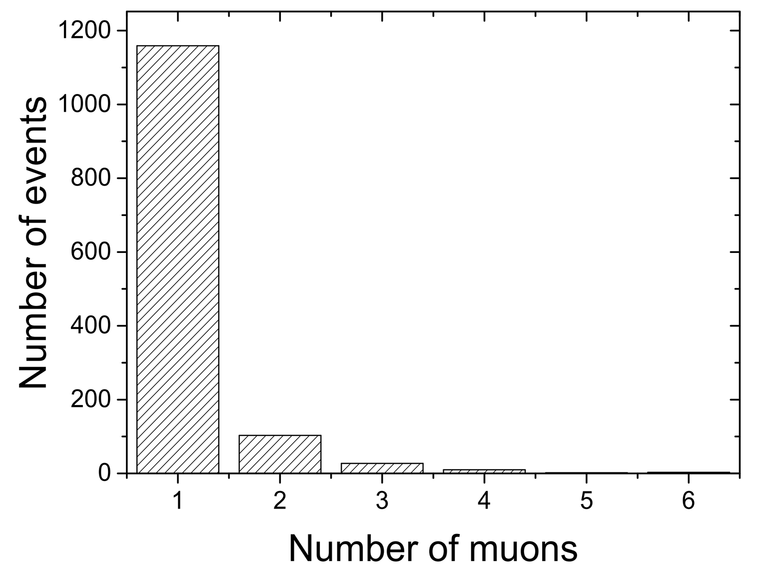


All delays in triggering system are finely tuned, so the time between the passage of the first particle in the event and the all-system trigger does not depend on the type of completed trigger condition and is approximately 225 ns, it takes 100 ns for cable delays and hardware jitters and 125 ns for triggering system. All signals from drift chambers should be received by TDC before the arrival of the NEVOD trigger because it stops it, so the delay of the trigger is necessary. For this purposes a special block for VME crate was developed, it combines galvanic isolation by rapid optocoupler, TTL to NIM converter (MC10124P) and 8 µs delay (SN74123N).

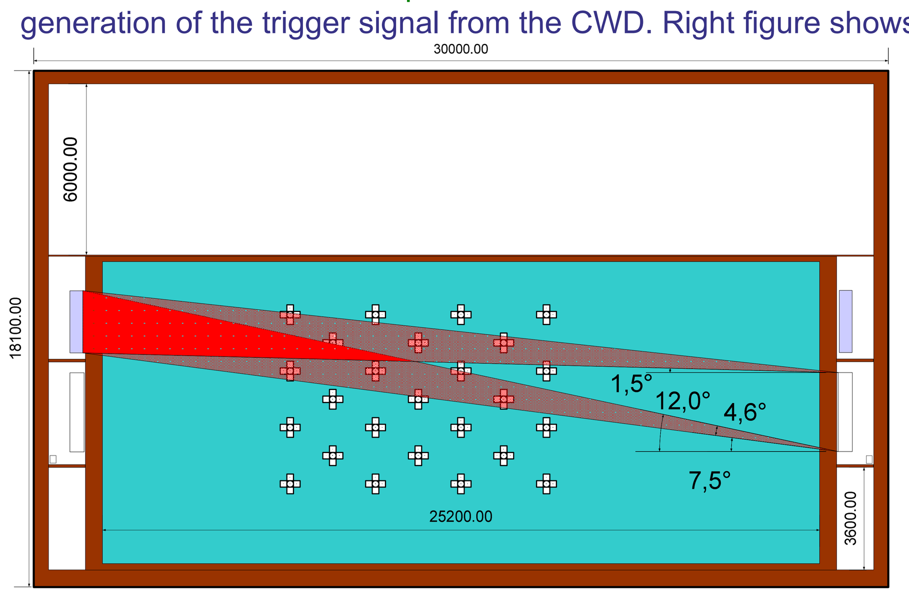
After the generation of the trigger signal in the triggering system, it transmits all its data to NEVOD central computer that starts (via Ethernet) to gather all amplitude information from CWD and configuration of triggered DECOR streamer tubes. Simultaneously NEVOD central computer sends network packet to CTUDC that contain main information about the event: number and time of the event, types of CWD and DECOR inner trigger signals, the number of hit CTS counters. Network packet starts with a 4 byte sequence at which the CTUDC central computer determines the type of received packet, decodes the data and starts to collect information from EM-4 TDC. After the primary data processing, the software of CTUDC central computer forms the event, later these events will be off-line joined with events saved at the NEVOD central computer by means of time marks and event numbers.

First results of joint operation of CTUDC with NEVOD-DECOR





The selection of events according to the type of the trigger in the NEVOD TS allows to investigate the temporal characteristics for each type of CWD and DECOR events. Left figure shows the distribution of drift times of electrons in one of the drift chambers for events triggered by CWD. The width of the distribution is about 6000 ns that corresponds to the maximum drift time of electrons. This indicates good stability of generation of the trigger signal from the CWD. Right figure shows the distribution of number of muons registered by CTUDC plane in these events.



A new trigger condition was used for cross-calibration of the CTUDC drift chambers and DECOR supermodules: it chooses events, which have triggered CWD and at least one DECOR supermodule. Range of possible muon tracks in such events and the relative position of CTUDC planes, CWD and DECOR supermodules are shown on the Figure to the left. The muons are moving under zenith angles ranging from 78° to 88° producing Cherenkov light to the most part of the CWD lattice. Rate of such events was about 0.2 s^{-1}.

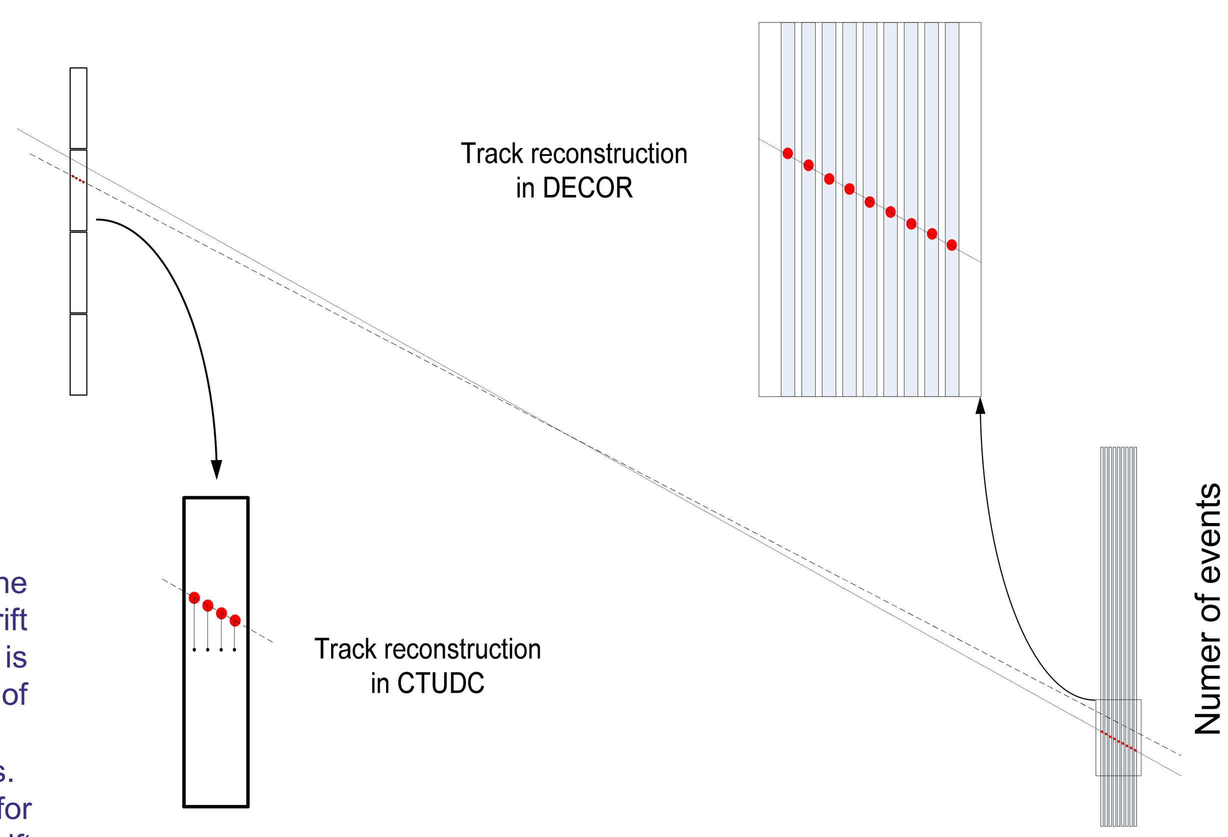
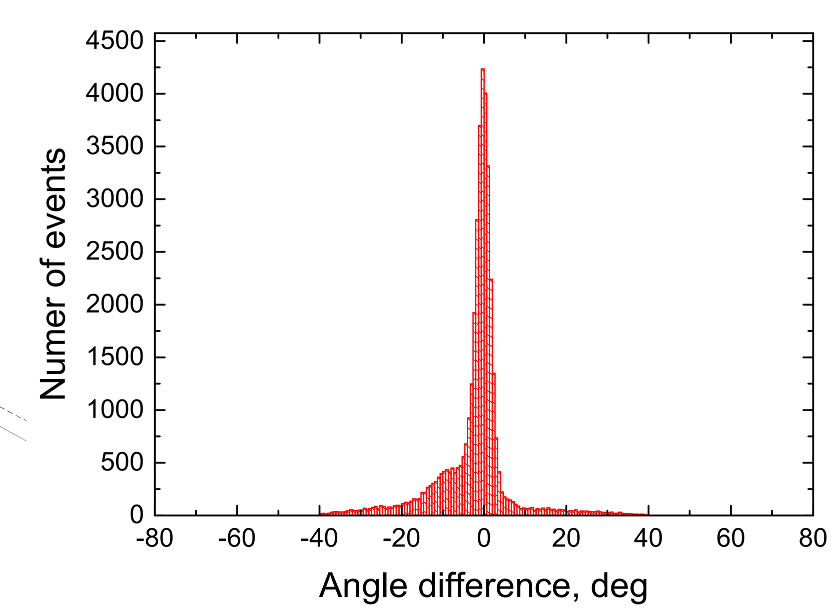


Figure shows the distribution in the difference in the muon track zenith angle estimates according to CTUDC and DECOR reconstruction. Taking into account the scattering of the muon in 26 m of water and 1.2 m concrete, as well as errors in the reconstruction of the angle in DECOR supermodules and drift chambers, the 7° RMS scatter can be considered as a successful proof of the efficiency of the coordinate-tracking detector CTUDC.



Conclusion

The unique coordinate-tracking detector CTUDC based on drift chambers from IHEP neutrino experiment is developed in MEPhI. Detector operates jointly with other systems of the experimental complex NEVOD and is aimed at registration of near-horizontal flux of muons generated by ultrahigh energy primary cosmic rays. Currently the detector is at the calibration stage. It has been already cross-calibrated with the coordinate detector DECOR and works jointly with Cherenkov water detector. First results of this work showed a good performance of the detector.

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http://ununevod.mephi.ru/en/