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Horizon-T experiment and detection of Extensive air showers with unusual structure

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Abstract. Horizon-T is an innovative detector system constructed to study temporary structure of Extensive Air Showers (EAS) in the energy range above ~10^{16} eV coming from a wide range of zenith angles (up to 80°). The system, located at Tien Shan high-altitude Science Station at approximately 3340 meters above the sea level, consists of eight charged particle detection points separated by the distance up to one kilometer. The time resolution of charged particles passage of the detector system is a few ns. This level of resolution allows conducting research of atmospheric development of individual EAS. The total of ~8500 Extensive Air Showers (EAS) with the energy above 10^{16} eV has been detected during the ~4000 hours of Horizon-T detectors system operations since October 24, 2016 to April 21, 2017. A notable number of events has a spatial and temporary structure that showed the pulses with several maxima (modals or modes) from several detection points of the Horizon-T at the same time as described further in this work. These modes are separated in time from each other starting from tens to thousands of ns. Some are further classified as unusual event with common structure.

1. Introduction

During the physics run 1 starting October 24, 2016 and ending April 21, 2017, more than 8500 of Extensive Air Showers (EAS) with the energy above ~10^{16} eV have been detected during the ~4000 hours of Horizon-T (HT) detectors system [1][2]. HT is located at the altitude of ~3340 meters above the sea level at the Tien Shan high Altitude Science Station of Lebedev Physical Institute of the Russian Academy of Sciences and is designed to observe the spatial and temporary structure of the EAS disks with the energies of primary particle starting from ~10^{16} eV.

In general, EAS has a typical structure arising from physics captured well by the CORSIKA [3] simulation software. Any reference to standard or usual EAS refers to the structure as simulated by CORSIKA. A simulated particle density per m^2 distribution with the distance from the EAS axis for the vertical primary proton with 10^{17} eV at HT location is shown in Figure 1.

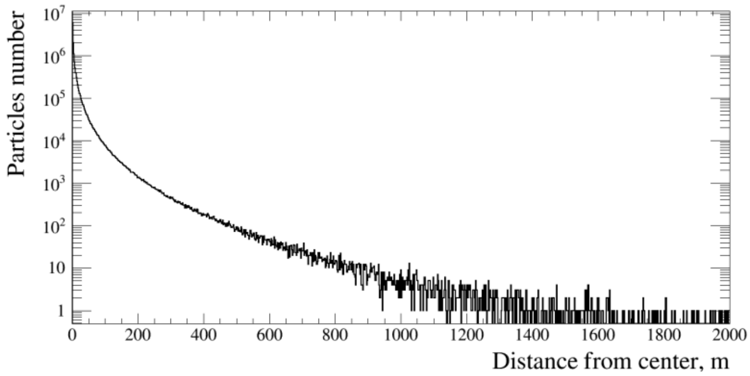

Figure 1: Particle density vs. distance from EAS axis for 10^{17} eV proton.

The time that it takes for the EAS disk to pass the observation level also changes with the distance from axis. The particle distribution in time comes lower and wider as illustrated in Figure 2. The shown histograms of particle number per time bin are taken at different distances from the EAS axis in 20m steps illustrating the sensitivity of the distribution to axis distance. If one would like to use this timing information, a detector used must have time resolution on the order of few ns. This timing information can be used in conjunction with particle density information for EAS analysis.

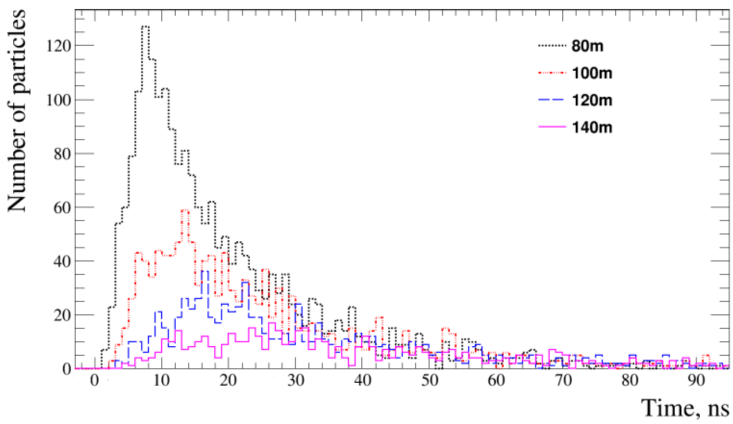

Figure 2: Number of particles arrival in time at different distances from EAS axis.

2. HT detector system

The HT detector system consists of eight active charged particle detection points and two that are under construction. The view from above of HT is given in Figure 3; active detection points are 1-8, distance between points 2 and 3 is ~900 m. Each active detection point has a 1 m^2 plastic scintillator detector (Sc) [4] with the R7723 Hamamatsu [5] Photomultiplier tube (PMT) that is parallel to the sky. In addition, near periphery points (1, 4-7) are also equipped with fast 0.25 m^2 glass detectors (Gl) [6]. Physics run 1 has taken place from Oct. 24, 2016 to Apr. 21, 2017 with ~4000 h uptime and ~8500 data events.

For the physics run 2, detection points 2, 9 and 10 will be equipped with plastic scintillator detection with cumulative areas of 5 m^2, 5 m^2 and 10 m^2 respectively. These detectors will be read out by MELTZ [7] FEU49 PMTs.

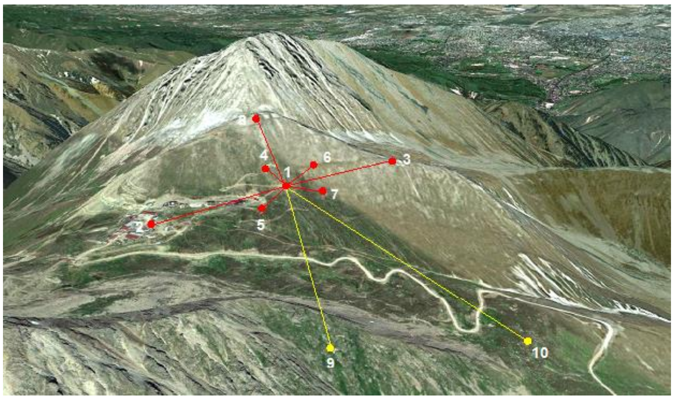

Figure 3: HT bird-eye view (detection points under construction in yellow)

A typical, or standard, EAS event from HT is recorded as a single peak from each active detection point, with peak area increasing towards the EAS axis while width is decreasing. The event is triggered by a signal in points 5 and 6; the offline selection is done to require a clear signal from at least four detection points. The example of the standard event is shown in Figure 4, with the event selected where axis is not passing near the detection point thus there is no single very large peak present. Pulses only from scintillator detectors are drawn. The pulse front time resolution for Sc are ~4-6 ns and for Gl are ~2-3 ns depending on the detection point distance to center.

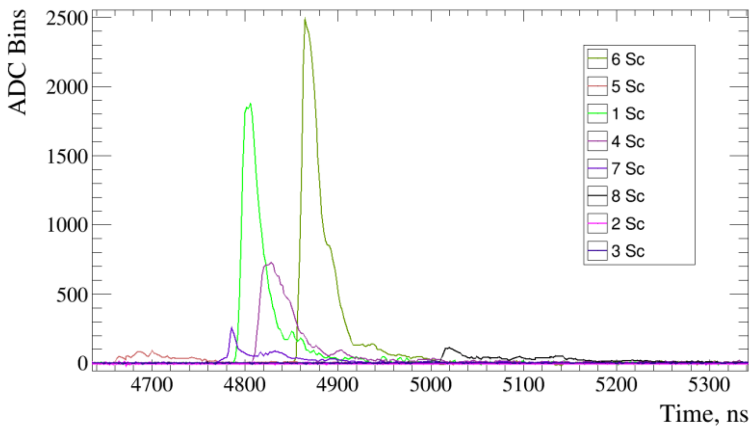

Figure 4: A typical EAS event at HT. Only scintillator detector responses are shown.

3. Unusual events at HT

After first reported observation in 1953 [8], numerous observations of the multiple peaks from EAS in the detectors separated by up to hundreds of ns have been reported and several studies have been conducted, but the mystery of these events remains without satisfying explanation. At HT, using the progressive time resolution achieved at all detection points, we have observed such events on a smaller time scale as well from numerous detection points. Illustrated in **Figure 5**, is the event that shows different time separation between the peaks at different detection points but demonstrating the same pattern in each channel, indicating that it's a part of a larger event with some specific trends.

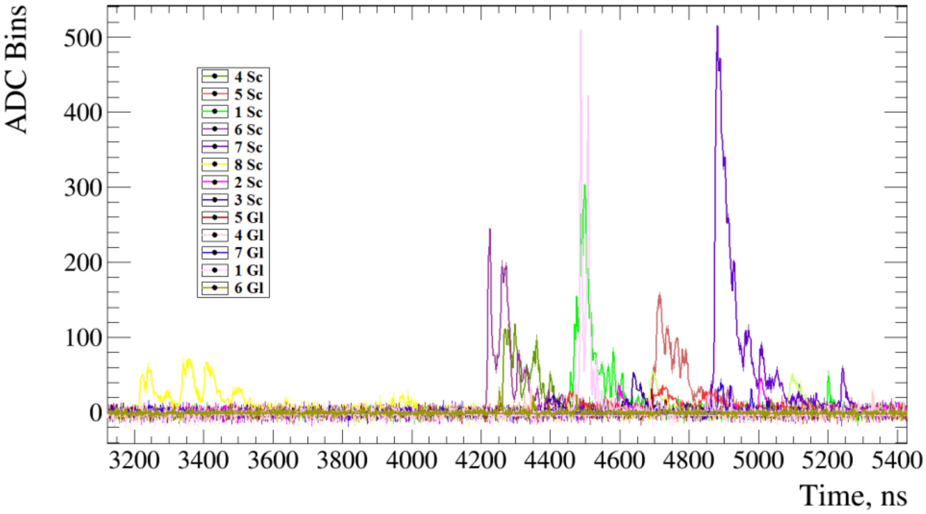

Figure 5: HT event with multiple peaks in different detectors.

It has been also noted that the multipeak, or multi-modal events (MME), are present in the events that have signals in all detection points, thus setting a possible energy threshold for such events above 10^{17} eV. After carefully reviewing events, we have found what appears to be a class of events exhibiting this behavior: central peak appears as single, then distance between multiple modes increases with distance from the center [9]. An example of such event is given in **Figure 6**. The events of this type have been called ‘unusual’ by HT collaboration.

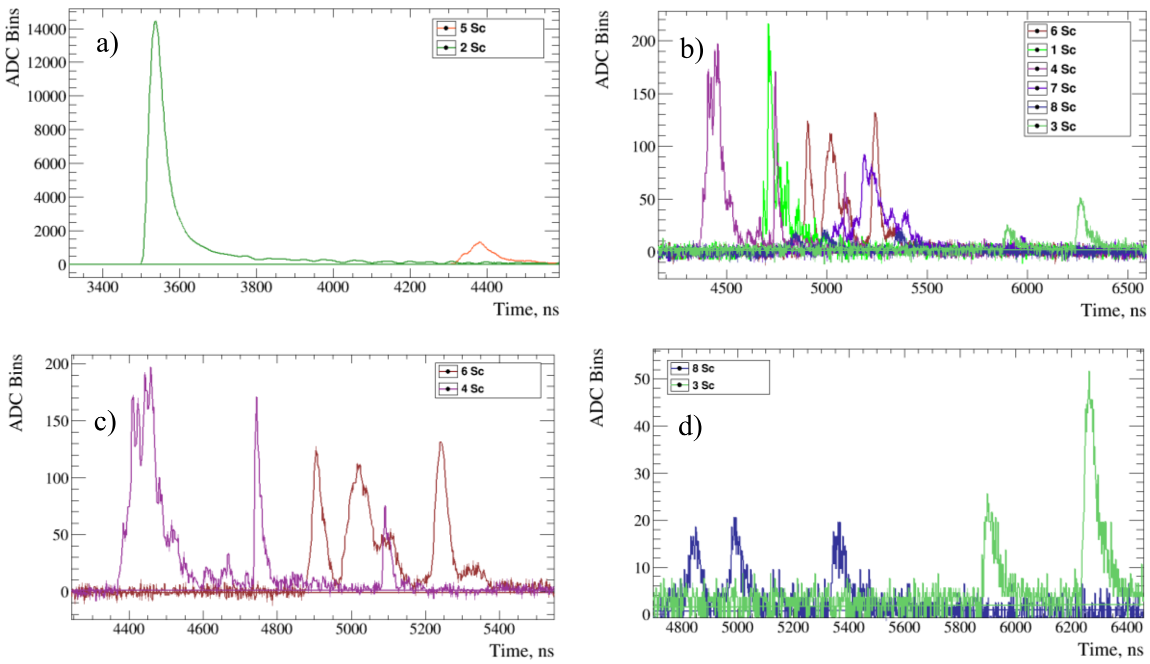

Figure 6: Example of unusual event: a) large peak close to EAS axis and next largest; b) smaller peaks exhibit multi-modal structure; c) and d) – time between peaks increases with distance from axis.

4. Conclusion

The 1st physics ran at the HT detector system has been completed successfully. It has yielded ~8500 data events in ~4000 h of uptime. The events can be classified as 'standard' – coinciding with simulated events in structure, and as 'unusual' – MME showing the pattern of increasing delays between successive maxima in each detector response with distance to EAS axis. The MME and unusual events all appear in the events with energy of the primary above ~10^{17} eV. To continue exploring this phenomenon, we started the construction of the new EAS detector HT-KZ [10] and have planned HT upgrades including introduction of the particle detectors based on liquid scintillator [11] detection medium.

Acknowledgements

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References

[1] Beisembaev R U et al. 2017 *Horizon-T experiment status* (Moscow: ISVHECRI-2016) EPJ Web Conf. **145** 11004
[2] Beznosko D et al. 2016 *Horizon-T Extensive Air Showers detector system operations and performance* (Chicago: ICHEP2016) PoS(ICHEP2016)784
[3] Heck D, Knapp J, Capdevielle J N, Schatz G and Thouw T 1998 *CORSIKA: A Monte Carlo Code to Simulate Extensive Air Showers* Forschungszentrum Karlsruhe Report FZKA-6019
[4] Duspayev A, Batyrkhanov A, Beremkulov T, Beznosko D, Iakovlev A and Yessenov M 2015 *The distributed particle detectors and data acquisition modules for Extensive Air Shower measurements at "HT-KZ" experiment* (Moscow: PhotoDet2015) PoS(PhotoDet2015)056
[5] Hamamatsu Corporation 314-5, Shimokanzo, Toyooka-village, Iwatagun, Shizuoka-ken, 438-0193 Japan
[6] Beznosko D et al. 2017 Fast and simple glass-based charged particles detector with large linear detection range *Journal of Instrumentation* **12** 7 T07008
[7] MELZ-FEU, 4922-y pr-d, 4c5, Zelenograd, g. Moskva, Russia, 124482
[8] Jelly J V and Whitehouse W J 1953 *Proc. Phys. Soc.* (London) **A66** 454
[9] Beznosko D et al. 2017 Extensive Air Showers with unusual structure (Moscow: ISVHECRI-2016) EPJ Web Conf. **145** 14001
[10] Duspayev A et al. 2016 *Simulation and design of the HT-KZ Ultra-high energy cosmic rays detector system for cosmic rays with energies above 10^17 eV* (Chicago: ICHEP2016) PoS(ICHEP2016)721
[11] Batyrkhanov A, Beznosko D, Iakovlev A and Yelshibekov K 2017 *Liquid scintillator composition optimization for use in ultra-high energy cosmic ray detector systems* (Moscow: ISVHECRI-2016) EPJ Web Conf. **145** 19016