Horizon-T Extensive Air Showers detector system operations and performance

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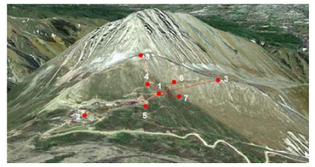
Abstract

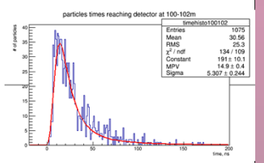
An innovative detector system called Horizon-T is constructed to study Extensive Air Showers (EAS) in the energy range above 10^{16} eV coming from a wide range of zenith angles (0° - 85°). The system is located at Tien Shan high-altitude Science Station of Lebedev Physical Institute of the Russian Academy of Sciences at approximately 3340 meters above the sea level.

It consists of **eight** charged particle detection points separated by the distance up to one kilometer as well as optical detector subsystem to view the Vavilov-Čerenkov light from the EAS.

The time resolution of charged particles and Vavilov-Čerenkov light photons passage of the detector system is **few ns**. This level of resolution allows conducting research of atmospheric development of individual EAS.



HT detector system from aerial view. 8 detection points are labeled.



Particles arrival time 100m away from EAS axis

Introduction to EAS

The Horizon-T (HT) detector system [1] realizes ideas that were first formulated in [2], [3]. The first results of the Horizon-T are published in [4] and [5] with another publication being prepared currently.

As EAS develops while passing through the atmosphere, ultra-relativistic electrons, muons and Vavilov-Čerenkov radiation photons each form a so-called shower disk up to 1 km or so. Calculations, carried using CORSIKA [6] EAS simulation software package, indicate that for vertically incoming EAS with primary particle energy ~10^{17} eV at the distance 100 m from the central axis the charged particles pass the observation level in ~15-20 ns to few ns near the axis. This sets minimal time resolution scale for HT.

With the increase of zenith angle the apparent thickness of the shower disks increases. The ability to conduct measurements at large zenith angles near to the horizon and the high time resolution give the name of the experiment: Horizon-T (where T stands for time).

Scintillator Detectors

Three scintillator detectors (SD), oriented perpendicular to each other in the x, y and z planes, are located at each detection point except point 8 that has only the z-plane one. The z-plane is parallel to the sky. This arrangement is needed for the angular isotropy in the registration of charged particles. SD uses polystyrene-based square-shaped cast scintillator [7] with 1 m^2 area and 5 cm width. SD detectors have either PMT-49 (FEU49B) [8] or Hamamatsu [9] R7723 PMTs

R7723 PMT and X-Y-Z SD detectors

VCD Detector

Čerenkov Detector

The Vavilov- Čerenkov radiation detector (VCD) is located next to detection point 1. It consists of three parabolic mirrors of 150 cm diameter and focal length of 65 cm. They are mounted on the rotating support allowing detection in zenith angle range of 0°-80° and in azimuthal angle range of 0° -360°. 15cm in diameter PMT-49Б (FEU49B) is located in the focal point of each mirror. The field of view of each mirror + PMT is ~13°.

From the geographical regions studied for the astroclimate, eastern Tien-Shan is well suited for Vavilov-Čerenkov radiation measurements [9] since for the most of the year there is a Rayleigh-type atmosphere when there is no aerosol present.

DAQ

CAEN DT5730 ADC

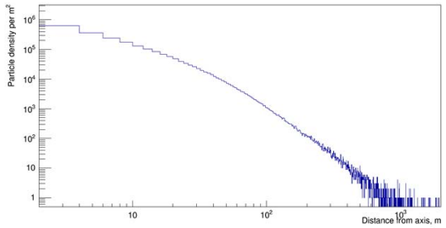
- **CAEN[11] DT5730 ADC**
  - 3 units with syncronization
  - 14bit 2V range
  - 8 channels
  - 125 ms conversion

Names of detection points

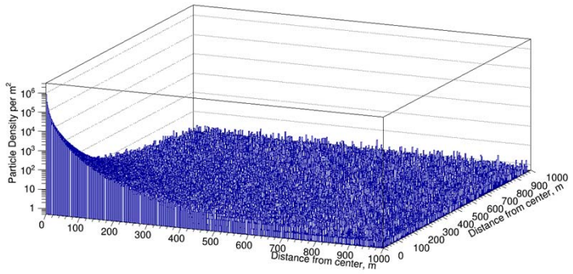
Station name	Center	Yastrebov	Stone Flower	Left	Kurashkin	Right	Bottom	Upper	Cher
Station number	1	2	3	4	5	6	7	8	VCD

Simulations – 'standard' EAS

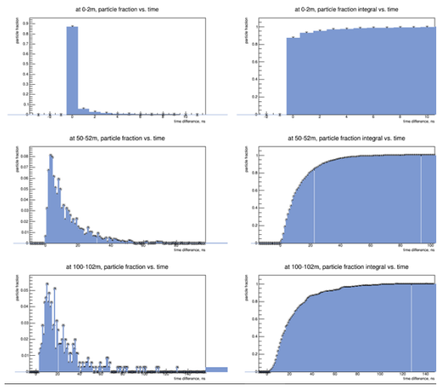
CORSIKA [6] simulation software is based on our current understanding of HEP, thus simulating a 'standard' shower. At observation level, such EAS has a single disk with particle density approx. $1/r^2$ from the axis and passage time growing as well. (Note that there is some problem with particle times near the axis as CORSIKA initially wasn't designed for time keeping). Plots are for E=10^{17} eV proton.



Particle density vs. distance from EAS axis

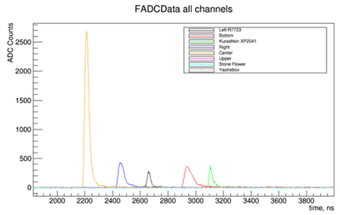


Particle density vs. distance from EAS axis



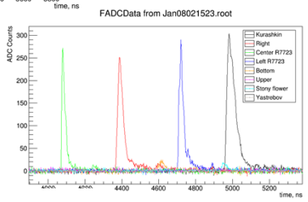
Time distribution of particles passage in simulated EAS vs distance from axis

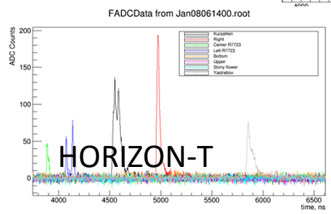
Standard and Unusual EAS



Standard EAS signal samples. If shower axis passed near any detection point there is one high peak and several smaller ones.

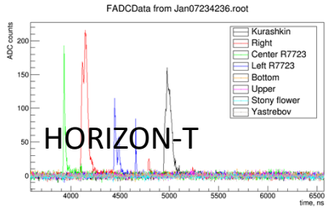
These signals can be reproduced by superimposing CORSICA output on detection points locations.

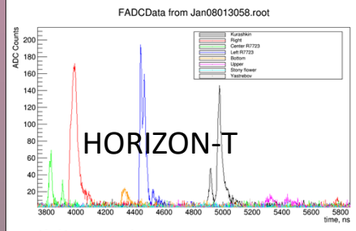




These are examples of 'unusual' EAS signals. All hardware has been calibrated to ensure signal purity.

Called 'multimodal', first observed by J. Jelly and W. Whitehouse [12], attributed to delayed particle effect at the time.





w/Horizon-T superior time resolution and full signal shape analysis, attribute multimodal EAS to new phenomena.
Work in progress

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