PROCEEDINGS OF SCIENCE

Detection points calibration at Horizon-T experiment

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Keeping the updated calibration values for scintillator-based detectors is a challenge for the detectors of cosmic rays, as the detectors are normally installed outdoors in the field, away from the controlled climate conditions of the lab. Changes in temperature and weather in general, and other external factors can influence the detector performance and need to be monitored and calibration values updated. This publication describes the procedure of monitoring the calibration settings from the Horizon-T detectors in the conditions of high altitude and for the case of the long data-carrying cables from each detector when access to each detector may not be possible or very difficult at certain times.

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1. Introduction

Horizon-T [1] is the detector system consisting of 12 detection points at distances up to 1 km from the center point. It has been designed to study Extensive Air Showers (EAS) with energy above 1016 eV coming from a wide range of zenith angles and aimed primarily at unusual events [2, 3]. 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. The aerial view of the system is presented in Figure 1 and the coordinates and distances from the center point are shown in Table 1. This information is the expansion of the previously reported configuration in [1] and [4] and is current for the physics run of 2021-2022.

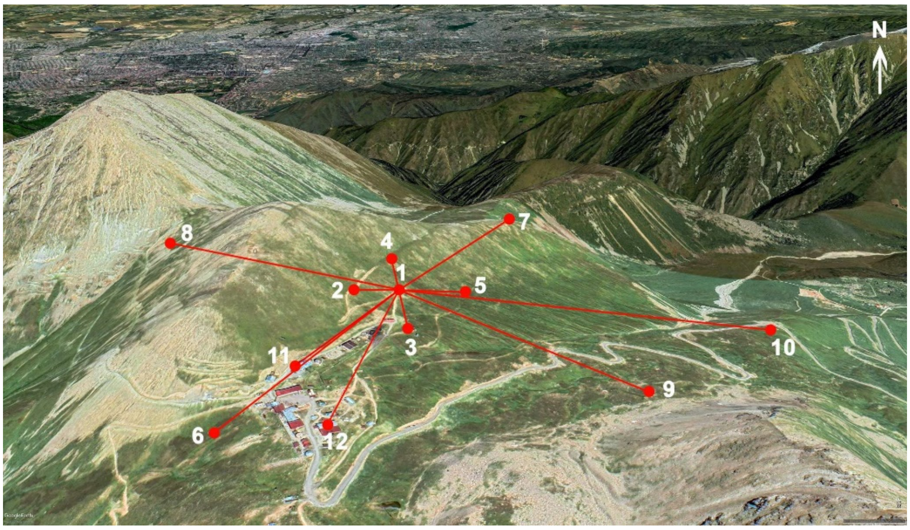

Figure 1: Horizon-T detector system from aerial view.

Table 1: Names, position and distance from reference point of the detection points.

Point #	Name	Latitude 43°	Longitude 76°	Elevation (m)	X(m) (North)	Y(m) (West)	Z (m)	R (m)
1	Center	2'49.73"	56'43.22"	3351.6	0.00	0.00	0.00	0.00
2	Left	2'48.07"	56'39.14"	3379.2	-51.23	92.34	27.60	109.15
3	Kurashkin	2'44.98"	56'44.70"	3329.1	-146.58	-33.50	-22.50	152.03
4	Right	2'53.84"	56'42.26"	3380.1	126.83	21.73	28.50	131.80
5	Bottom	2'52.60"	56'50.19"	3309.2	88.57	-157.75	-42.40	185.82
6	South	2'33.45"	56'30.86"	3325.2	-502.37	279.74	-26.40	575.61
7	North	3'8.37"	56'55.67"	3306.1	575.24	-281.78	-45.50	642.16
8	West	2'56.09"	56'17.63"	3376.2	196.27	579.18	24.60	612.02
9	East	2'40.92"	57'6.54"	3252.0	-271.87	-527.80	-99.60	602.00
10	Distant	2'57.36"	57'26.49"	3125.3	235.46	-979.33	-226.30	1032.34
11	PhysTech	2'38.64"	56'36.02"	3356.0	-342.22	162.96	4.40	379.06
12	Elling	2'32.94"	56'39.73"	3347.0	-518.11	78.99	-4.60	524.12

1.1 Detection points

At each detection point, there is a single scintillator detector (SD). Each SD is based on the polystyrene-based square-shaped cast scintillator [4, 5] with 1 m^2 area and 5 cm or 10 cm thickness. Each detector in points 2–5 has Hamamatsu R7723 PMT (recently relabeled as H11284-30). All other detection points are equipped with the Hamamatsu H6527 PMT.

In addition, point 1 is equipped with glass-based fast detector with the detection medium area of 76×82 cm^2 and a thickness of 3 cm with Hamamatsu R7723 PMT readout.

Each detector is oriented in the XY plane (horizontal) and is connected to a data acquisition system located in the detection point 1 by a high-frequency cable.

1.2 DAQ

The DAQ system consists of up to 3 CAEN DT5730 FADC (flash analog to digital converter). Unit designated as 'master' generates the primary trigger pulse from preset conditions, then trigger is fed into the fan-in-fan-out unit that outputs triggers for all three boards to record the event. Trigger pulse can also be recorded for the sync between the boards. Trigger pulse is exported to other detector systems.

2. Detector calibration stability

To keep the accuracy of the data during the physics run, regular calibration of the detectors is required. At Horizon-T location, the physics run is from early Fall to late Spring as the Summer is the thunderstorm season that prevents detector operations. Due to high altitude location, access to individual detector points may be impossible for prolonged periods due to snow and other weather hazards. Additionally, most points have only a single cable connecting them to DAQ.

The monitoring and calibration procedure used takes advantage of the detector average signal frequency of MIP (minimally ionizing particle) signal being stable. This gives the ability to find the MIP value over a different cable (the cable from detection point to DAQ vs. the cable used during calibration with a telescope at the point) and to monitor the detector performance and PMT gain by monitoring the average event frequency at the MIP or other threshold values. The detailed procedure is provided in section 2.1 below.

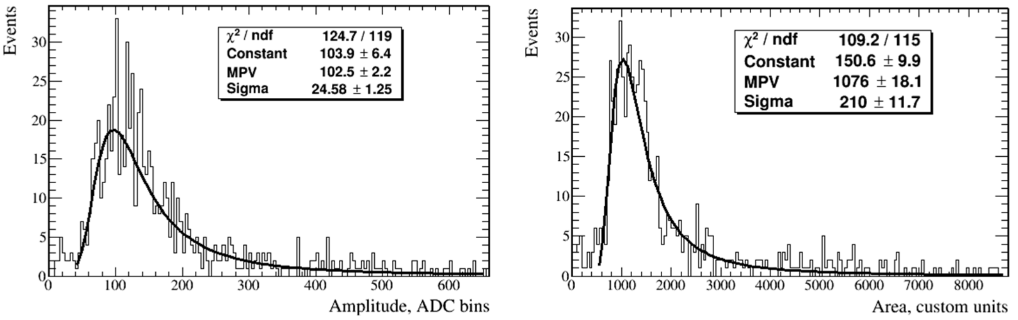

Figure 2: Detector MIP response amplitude (left) and area (right)

2.1 Calibration Monitoring Procedure

1. Calibrate a detector using the external trigger (telescope) to obtain the MIP response amplitude MIPa, and area MIP_s, using a Landau curve fit – see Figure 2 (left) for the amplitude fit and Figure 2 (right) for the area fit. This calibration is done at each point position locally.

2. Measure the trigger frequency f(U) at various threshold values U and obtain the integral amplitude spectrum. Express U in the number of MIP, n

3. Above a certain value of $n > n_1$, approximate as $f(>n) \approx A\, n^{-k}$. From this approximation, can express $n = \left(\frac{A}{f(>n)}\right)^{1/k}$

4. Plot $\log_{10} f \;\; vs \log_{10} n$ and do linear fit. Figure 3 (left) shows a fit for all n, and Figure 3 (right) shows the fit for $n > 1.6$ MIP.

5. Fit line equation is: $\log_{10} f(>n) = A - k\log_{10} n$, where A is the 'offset' and k is the 'slope' in this context.

6. Next, for multiple threshold amplitudes U′, as measured at the DAQ location, get a new integral spectrum F(U′). Note that U′ and U are different due to connecting cables lengths. The threshold value U_{th} can be related to number of MIP using results from Figure 3 (right) as: $n_{th} = \left(\frac{A}{F(U')}\right)^{1/k}$

7. Now can get MIP response amplitude MIPa′ as: $MIPa' = \frac{U_{th}}{n_{th}}$

8. MIPa′ can also be expressed as: $MIPa' = k_{tran} \cdot k_{exp} \cdot MIPa$, where k_{trans} and k_{exp} are the coefficients of transmission attenuation and pulse expansion (widening) that occur due to the cable. From that, $\mathrm{MIP\_s}' = \mathrm{k_{trans}} \cdot MIP\_s$ and $MIP\_s' = MIP\_s \cdot \frac{MIPa'}{k_{trans} \cdot MIPa}$

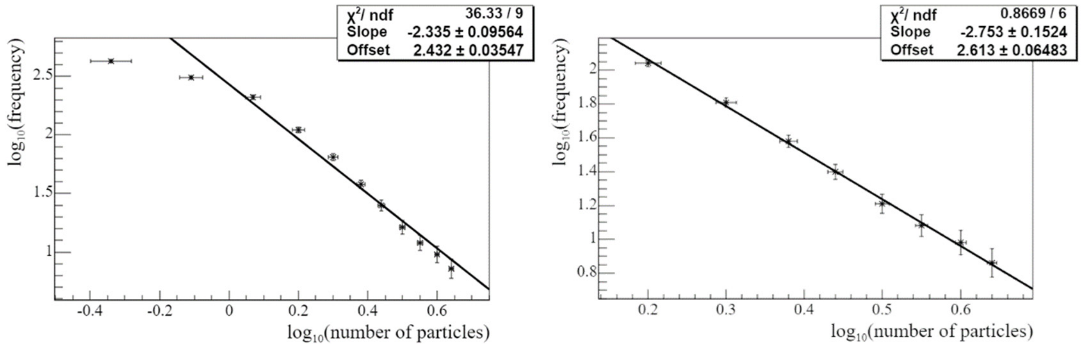

Figure 3: (left) All points are included in the fit. (right) Only points above n_1 *are included.*

3. Conclusion

With frequent monitoring of number of triggers at various threshold values from the DAQ, the detector performance can be assessed by obtaining the updated values of MIP response amplitude and area and the correspondence of trigger threshold to number of MIPs. The results of the practical applications of this calibration procedure will be provided once the testing of the procedure is fully completed.

References

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