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Some properties of two cosmic ray stations appertained to the GELATICA Network in Georgia

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Abstract: Hereinafter some results obtained by the **GELATICA** Network (Georgia) of Cosmic Rays (CR) stations recording Extensive Air Showers (EAS) events are described. The specific data from EAS goniometers operating in Tbilisi and Telavi are presented. The influence onto the form of estimated distributions of the EAS arrival directions induced by the disposition of detectors and of matter surrounding the installations is shown.

Keywords: extensive air shower, cosmic rays stations' network, EAS arrival direction estimation.

1 Introduction

There exists the special problem of investigation of High Energy CR by means of spatially separated detector systems timed by the **G**lobal **P**ositioning **S**ystem (GPS). Particularly, there exist some interactions of primary CR in near or deep space with interstellar and interplanetary matter that possibly would produce several particles or even a jet of particles propagating towards the Earth [1]. These particles could produce a set of detectable EAS within a short time interval, separated by large distances. These effects are very rare, but during last years of the past century there has appeared some observational evidence of their existence [2,3,4]. The problems of last type are widely researching along last time. The projects for this purpose are running in North America [5-10], in Europe [4,11-14] and in Japan [3]. Project named GELATICA (**GE**orgian **L**arge-area **A**ngle and **TI**me **C**oincidence **A**rray) is devoted, *inter alia*, to creation and development of the network of tiny CR stations over the area of Georgia [15].

The GELATICA project has an educational component, so all prospected stations have to be allocated in sites of high schools and universities over Georgia [15]. It is during last four years that first two CR stations of the GELATICA network are operating in Andronikashvili Institute of Physics (Tbilisi State University) ("TBS") and Gogebashvili University in Telavi ("TEL") [16,17]. These stations are operating as EAS goniometers. The goniometer is an installation consisting of a detector system, registering the times of EAS particles passages through detectors [18]. This information allows estimation of the EAS arrival direction by means of the relative delays of the signals mentioned.

The UTC (**U**niversal **T**ime **C**oordinated) moment of EAS arrival is registered simultaneously by the GPS unit, allowing to investigate space-time correlations of EAS with energies $>10^{15}$eV.

Some basic facts concerning properties of both installations have been published earlier [19,20]. Every installation in our case consists of only 4 detectors due to the standard equipment used [21]. That is why any direction estimations are forcibly constrained by the flat EAS front approximation. The flat goniometers (i.e. with all detectors in common plane; the goniometers of that sort possess some essential fault [20]) are used by the same reason. Temporal resolution (digitization step) of signals provided by the equipment used is 1.25ns.

2 Installation in Telavi

The TEL goniometer is disposed in Telavi on the ground floor of rather heavy construction. Respective rate of events' registration has proved to be (2.06 ± 0.03) EAS/h. Detectors are disposed in the corners of rectangle with sides dimensions $2.7\text{m} \times 5.2\text{m}$ approximately. The overall disposition of detectors is oblong, consequent to the room form. Total number of 3817 EAS events have been recorded during this installation operation period. Every direction is specified by the projection of the EAS front unit ort onto the special plane parallel to the detectors' plane. Just these values are estimated immediately by the flat goniometers from the registered data of the times of the shower particles passage through detectors. Positions of the ends of these projections of orts' estimations are shown on the **Fig. 1** by the crosses in the zenith vicinity (i.e. of the (0, 0) point). The average position of all directions recorded is reliably distinguishable with the zenith direction: $\theta_z = 14.4° \pm 0.4°$. This shift can be explained by the asymmetric location of installation – absorbing material depth is strongly dependent on direction.

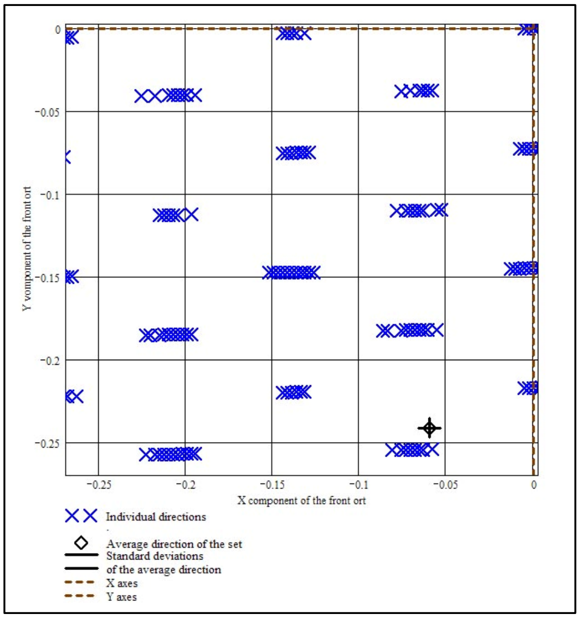

Fig. 1. TEL goniometer. Projections of EAS front orts onto the special plane parallel to the detectors' plane.

Observable discretization of measured directions is a direct sequence of digitization of registered times of particles passage through detectors, which realizes the hardware used [21]. The points of estimated directions are clustered in stripes. All points are located around the vertexes of rhombuses in ort projection plane and their positions are somewhat fuzzy. This peculiarity is due to the oblongness of the installation. On the contrary, in the case of axial symmetric plane goniometer with detectors disposed in the vertexes of square, the points representing measured directions have to be located exactly in the vertexes of squares on the ort projection plane. This prediction is proved by the results of TBS goniometer, see below. **Fig. 4.**

Obvious consequence of this specific arrangement of measured EAS arrival directions are peculiarities of the angular distributions. The distribution of zenith angles appears (due to digitization) to be composed of a sequence of short spikes under big resolution, while it is rather smooth (**Fig. 2**) under large histogram cells charges

It is considerable that the zenith angles distribution measured by the TEL goniometer appears to have a noticeable amount of recorded events near the horizon, while it contradicts with the known behavior [22] of the distribution. This distortion of distribution observed is connected with small geometrical dimensions and flatness of the installation.

In addition, the apparent deviation of measured azimuth distribution from the anticipated uniform distribution is revealed (**Fig. 3**).This difference is a consequence of the anisotropy of the matter surrounding the installation.

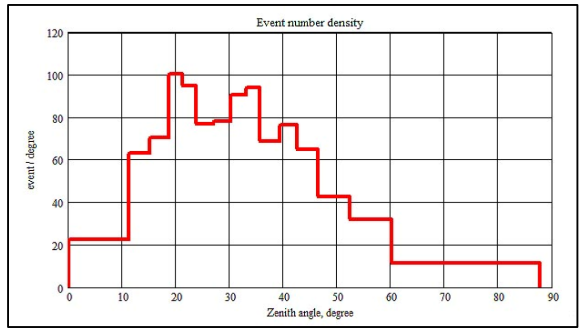

Fig. 2 The histograms of zenith angles distribution acquired by TEL goniometer.
The histogram cell charge is 250 events/cell

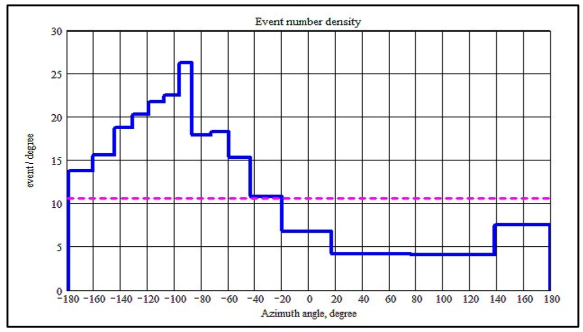

Fig. 3. The histograms of azimuth angles distribution acquired by TEL goniometer

The histogram cell charge is 250 events/cell
The anticipated uniform distribution is shown too

3 Installation in Tbilisi

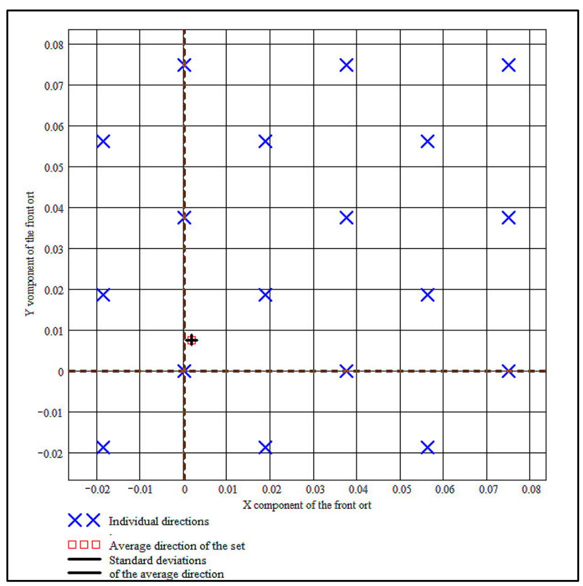

Fig. 4. TBS goniometer Projections of EAS front orts onto the special plane parallel to the detectors' plane.

The TBS installation is disposed in the roof space of second building of Andronikashvili Institute of Physics. The concrete layer above it is relatively thin and the rate of events' registration is comparatively high: (12.5 ± 3.2) EAS/h. Total number of events registered = 52798. The distance between detectors is equal to 10m and they are placed *symmetrically* in the corners of square. This special arrangement results in the distributions observed. As it can be seen on the **Fig.4**, the average EAS direction only slightly differs in a sense from zenith direction (i.e. $\theta_z = 0.45°\pm0.07°$), though the deviation is statistically significant.

Discrete points of the ends of the registered projections of directional orts' estimations are arranged in the corners of squares. The comparative increase of distances between the detectors entails two welcome consequences, at least: the representing points of orts' tips are arranged much closer one to another – i.e. the angular resolution has increased (cf. **Fig. 2**) – and density of points in the horizon vicinity has decreased, as can be seen from the distribution of zenith angles (**Fig. 5**). Therefore, the goniometer in this configuration can represent more accurately the true distribution of EAS arrival zenith angles.

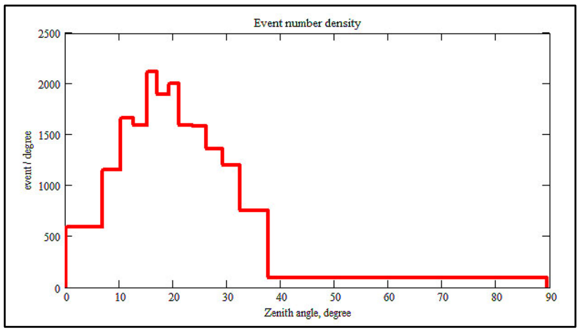

Fig. 5. The histograms of zenith angles distribution acquired by TBS goniometer The histogram cell charge is 4000 events/cell

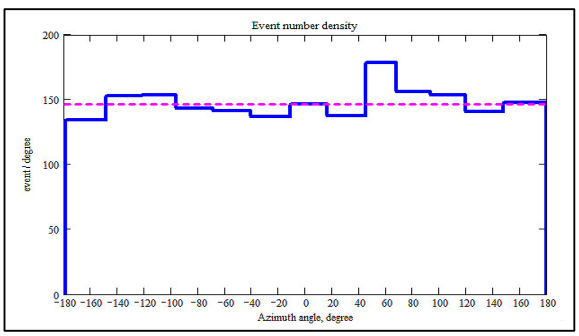

Fig. 6. The histograms of azimuth angles distribution acquired by TBS goniometer. The histogram cell charge is 4000 events/cell. The anticipated uniform distribution is shown too

The angular distributions certainly reproduce the statements described just above. The distribution of zenith angles (**Fig. 5**) in this case is considerably narrower (cf. **Fig. 3**) as the overall dimension of the installation is greater. Nevertheless the distribution appreciably spreads until the 90° zenith angle value. This feature is unnatural and indicates certain imperfection of the installation. Undoubtedly, it is a sequence of the flatness of the goniometer used and of the lack of the number of detectors.

The distribution of azimuth angles (**Fig. 6**) is visually "as if" uniform, but χ^2-test does not confirm this expectation, i.e. the shift of the event's center from zenith position is verified.

The values of standard deviations of zenith (θ) and azimuth (φ) angles of EAS arrival directions have been estimated for every event registered. Dependences of sector-average values of these deviations on the zenith angle value are shown on **Fig. 7.** The respective approximations derived previously [20]:

$$\sigma_\theta(\theta) = \sigma_h / \cos(\theta); \qquad \sigma_\varphi(\theta) = \sigma_h / \sin(\theta);$$

are shown too.

Here $\sigma_h = 0.05692\pm0.00004$ ($\sim 3.261°\pm0.002°$) is the average value of the standard deviation of horizontal projections of EAS direction ort. Slight data deviation from the approximation lines in the horizon vicinity is connected with violation of the surrounding matter symmetry for those directions.

4 Conclusion

Executed results comparison makes it possible to assert that the crucial influence onto the resolving power of plane goniometers exert at least two factors: the overall dimension of the installation and the finite temporal resolution of signals. The predictable influence of form, arrangement and surroundings of the installation on the angular distributions observed is reasserted.

Meanwhile it has appeared that small installations heavily overestimate the relative EAS flow near the horizon. So, the dimension increase of installation reduces this side effect simultaneously with growth of the resolution of goniometer. Further development of the quality of goniometers is available by means of the grows of number of detectors, as well as by force of increase of distances between detectors, together with actual turn towards practical application of the axially symmetric 3D structure of EAS goniometers [19,20].

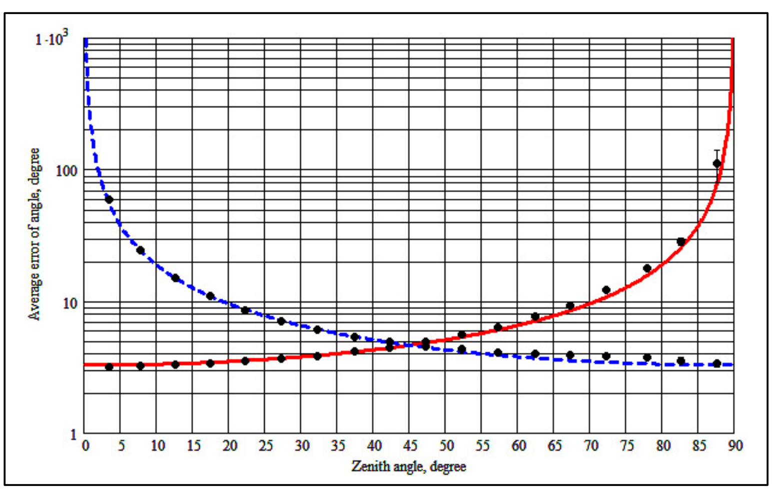

Fig. 7. TBS goniometer. Dependences of standard deviations of EAS direction angles on the zenith angle.

Solid line approximates zenith angle standard deviations' average

Dash line approximates azimuth angle standard deviations' average

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