

NEW DATA ON THE DIFFERENCE OF PARAMETERS OF EAS SELECTED ACCORDING TO THEIR SIZE OR CHERENKOV LIGHT FLUX.

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Abstract

Investigation of EAS parameters using shower and Cherenkov arrays was performed. It were revealed reliably a number of quite new peculiarities in EAS development.

Unique data were received at comparison of parameters of EAS selected according to their size N or to the Cherenkov light flux Q . It is shown that established big difference of all EAS parameters at such approach is connected with difference in development of EAS initiated by protons and nuclei. Showers started by nuclei develop, reach its maxima and attenuate faster than those initiated by protons. It is the reason why EAS selected according to their size are initiated mostly by protons. And it is the reason why EAS size does not connect adequately with primary particle energy. Comparison of distributions $W(Q)$ at $N_1 = 1,15 \cdot 10^6$ and $N_2 = 8,3 \cdot 10^6$ particles demonstrates their rapid change, indicating on the fast shifting of shower maximum deep into the atmosphere (for showers initiated by protons): greater showers are accompanied by relatively less flux of Cherenkov light, which is irradiated mostly from the region of shower maximum. It is possibly to understand in the assumption on big role of unstable particles because their decay length increases rapidly with its energy.

1 Tien-Shan EAS array.

Tien-Shan complex array [1] has 112 scintillator detectors with sizes of $S = (0,25 - 1)m^2$ controlled the area inside the circle with radius $R=70$ m, and 10 Cherenkov detectors placed at distances from 0 up to 300 meters from shower array center. Seven nearest detectors ($R < 110$ m) consist of single phototube with photocatod diameter $d=15$ cm looking up. Three distant detectors at distances 165, 240 and 301 meters contain 9, 18 and 36 analogous phototubes. Such installation with dense central part have permit to estimate the EAS axis position with accuracy not worst than 2 meters.

2 Events selection

Only showers with $N > 10^5$ particles which axis striked the circle with radius $R < 30$ m and had zenith angle $\theta < 45^\circ$ were used for analysis. From these showers only those for which the flux of Vavilov-Cherenkov photons was measured in the ring with radii 50 and 150 meters were selected for the consequent analysis. The last condition was used because our Cherenkov

array was not simmetrical enough. EAS size spectrum has differential slope $\gamma = - 2,87 \pm 0,06$ at $N > 1,5 \cdot 10^6$ particles in excellent agreement with previous Tien-Shan data [2]. The lateral distribution of Cherenkov photons is in good agreement with calculations of Lagutin et.a.[3] for primary proton at $E = 10^{16}$ eV.

3 Results.

The value of Vavilov-Cherenkov light flux Q is connected the most adequately with energy of primary particle, because attenuation of light in the atmosphere is small and integration of photon flux on its lateral distribution permits to eliminate its fast change with energy. Differential spectra of Cherenkov photon fluxes in EAS have slopes $\gamma = - 2,66 \pm 0,097$ for showers with $N > 10^6$ particles, but $\gamma = - 3,04 \pm 0,07$ for showers with $N > 10^5$ particles. Earlier [4] we (assuming the adequate connection between EAS size and primary energy) had presented wrongly the first value.

We have compared dependencies $N(Q)$ and $Q(N)$. They are shown in fig.1. It is possible to see that these dependencies are not coincide: shower array selects EAS with bigger size, but Cherenkov array selects shower with equal primary energy and thus include showers attenuated in the atmosphere and having smaller size. Dependencies of shower age $S(N)$ and $S(Q)$ are shown in fig.2. It is seen that EAS selected by shower array are younger and this difference increases with energy. We can see from these 2 figures, that shower arrays select mostly EAS initiated by primary protons at each fixed size and discriminate more old showers initiated by primary nuclei, which develope, reach their maximum and attenuate faster than those initiated by primary protons. It is possible to conclude from here that EAS size does not connect adequately with primary particle energy and thus EAS size spectrum does not reflect adequately the energy spectrum of primary cosmic rays.

It were compared distribution of showers on EAS size N at fixed value of Cherenkov light $Q_{fix} = (3,16 - 4,22) \cdot 10^{10}$ photons (here $\langle Q_{fix} \rangle = 3,6 \cdot 10^{10}$ photons, $\langle N \rangle = 8,18 \cdot 10^5$ particles) and distribution of EAS on Cherenkov light flux Q at fixed size of shower $N_{fix} = (1,00 - 1,33) \cdot 10^6$ particles (here $\langle N_{fix} \rangle = 1,15 \cdot 10^6$ particles, $\langle Q \rangle = 3,53 \cdot 10^{10}$ photons). It is very important to point out that both distributions have equal value of Q . To plot these distributions on the common graphic we have put value of $\langle Q \rangle$ of last distribution at position of $\langle N_{fix} \rangle$ on abscissa (see fig3). It is seen that the right part of distributions coincide, but the first distriburion is much wider than the second one because Cherenkov array selects many small showers initiated by nuclei and attenuated in the upper part of atmosphere. Showers initiated by nuclei (left part of the first distribution) have in 3,04 times less number of particles and their age is 0,07 greater in comparison with those initiated mostly by protons (right part of the first distribution).

We have compared the distribution of showers size $W(N)$ at fixed flux of Cherenkov light $Q_{1fix} = 3,16 \cdot 10^{10}$ photons with those at $Q_{2fix} = 1,95 \cdot 10^{11}$ photons. The first distribution was shifted along the abscissa in 6,17 times. It is possible to see from fig.4 that approximately 24% of showers at greater value of Q has much less size N and value of $S = 0,97$ in comparison with $S = 0,86$ for showers at $N > 10^6$ particles. Possibly these showers were initiated by very heavy primaries started them in the very beginning of the atmosphere.

It were compared the distribution of Cherenkov photons flux $W(Q)$ at fixed EAS size $N_{1fix} = 1,52 \cdot 10^6$ particles with those at $N_{2fix} = 8,31 \cdot 10^6$ particles. The first distribution was

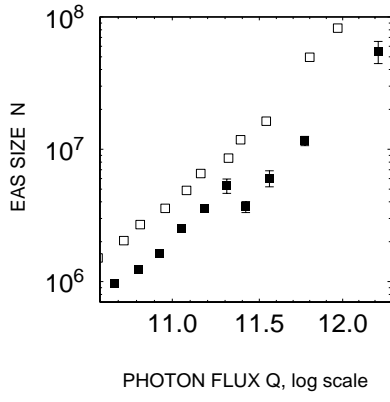


Figure 1: *Dependencies $Q(N)$ -open squares and $N(Q)$ -black.*

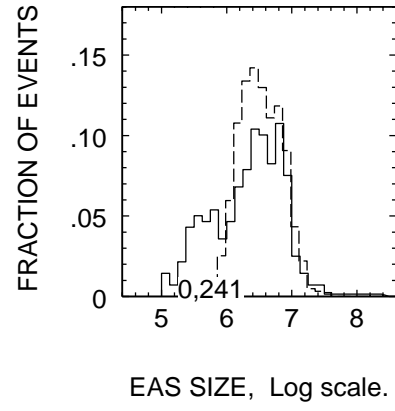


Figure 4: *Distributions of EAS on N at fixed flux of Cherenkov light $Q_1 = 3,6 \cdot 10^{10}$ -dashed line and $Q_2 = 1,1 \cdot 10^{11}$ -solid.*

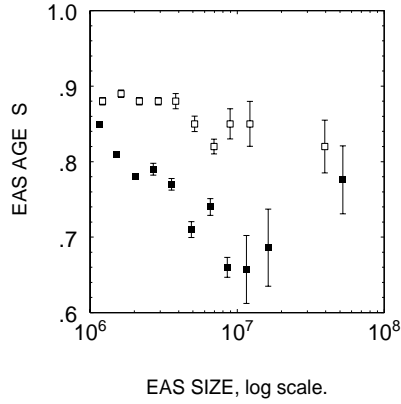


Figure 2: *$S(Q)$ -open squares and $S(N)$ -black.*

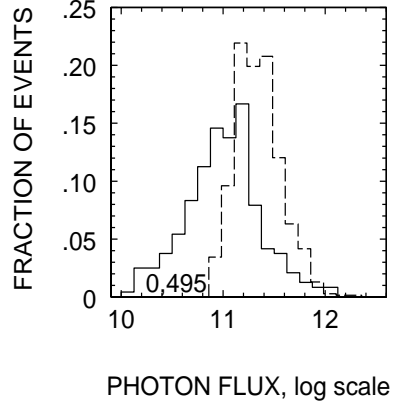


Figure 5: *Distributions of EAS on Cherenkov light flux Q at fixed shower size $N_1 = 1,15 \cdot 10^6$ -dashed line and $N_2 = 8,31 \cdot 10^6$ -solid.*

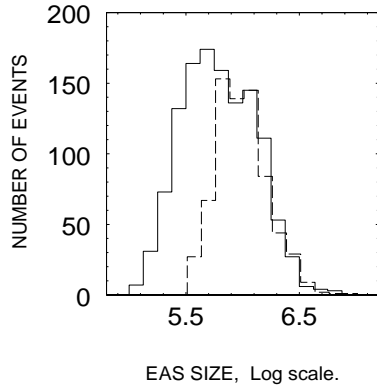


Figure 3: *Distributions of EAS: on shower size N at fixed $Q = 3,6 \cdot 10^{10}$ -solid line and on Cherenkov light flux Q at fixed $N = 1,15 \cdot 10^6$ -dashed line.*

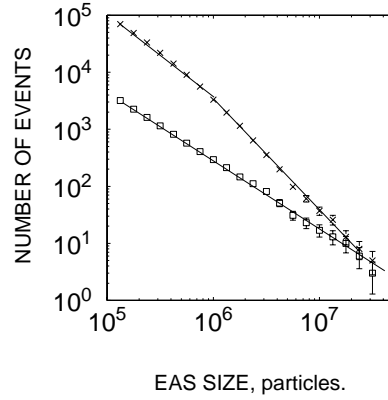


Figure 6: *Differential EAS size spectra: upper - all showers, lower - young showers.*

shifted along the abscissa in 5,47 times. It is possible to see from fig.5 that at greater size of showers relative flux of Cherenkov photons is much less and the fraction of such showers reaches near 50% for which value of $\langle Q \rangle$ is 2,44 times less than $\langle Q \rangle$ for the total distribution or in 3,85 times less than for other half of showers. Because the essential part of Cherenkov photons are irradiated from the region close to EAS maximum the last result indicates on the rapid shift of shower maximum position deep into atmosphere with increasing of EAS size: the less particle's path in the atmosphere - the less Cherenkov light they irradiate. This conclusion is supported by fast narrowing of Cherenkov photons's lateral distribution and decreasing of age for EAS selected by shower array (see fig.2).

Results received are in a good coordination with data [5] on the fast increasing of young EAS ($S = 0, 20 - 0, 60$) fraction in the the total flux of showers: it increases in 10 times when EAS size changes from $N = 10^5$ to $N = 10^7$ particles as it is possible to see from fig.6. By this EAS size spectrum of young showers (initiated mostly by protons) is very hard: $\gamma_{diff}=2,2$. We believe that it is impossible to account for such hard spectrum without the assumption on the increasing role of unstable particles (so-called "long flying component") in the EAS development: decay lenght of unstable particles increases rapidly with energy, that makes spectrum of young showers very hard.

4 Conclusion.

- 1) Shower arrays select EAS which were initiated mostly by primary protons. Showers initiated by nuclei of the same energy (as protons) have in 3-3,5 times less size and at this (in 3 times less) size supplies only $\sim 4,3\%$ in differential flux of all showers: $((1/3)^{2,87} = 0,043)$.
- 2) The EAS size does not connected adequately with initial energy of particle. It follows from the big difference of parameters of showers initiated by protons or nuclei. Thus EAS size spectrum does not reflect adequately the energy spectrum of primary cosmic rays.
- 3) Rapid relative decreasing of Vavilov-Cherenkov light flux when EAS size increases indicates on the fast shifting of shower maximum deep into atmosphere, that conformes as by decreasing of shower age so as by narrowing of Cherenkov photon's lateral distribution.

In our opinion results presented in this paper support the assumption on the increasing (with energy) role of unstable particles with heavy quarks in EAS development.

References

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