MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescope

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Effect of the Earth Magnetic Field on MAGIC Shower Images

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Abstract

We used simulated sets of gamma showers with zenith angle of 10°, 20°, 30° and about 40° and two azimuth angles 0° (North) and 90° (East) each (with NSB included but without any starfield simulation) to check the influence of Earth magnetic field on shower images of MAGIC telescope. The significant effect is seen on effective collection area for small shower energies, but a simple correction: the change of a discrimination trigger level diminishes the "North-East asymmetry" very much and it seems that eventually corrections are not needed (to some reasonable accuracy required).

1 Image cleaning procedure

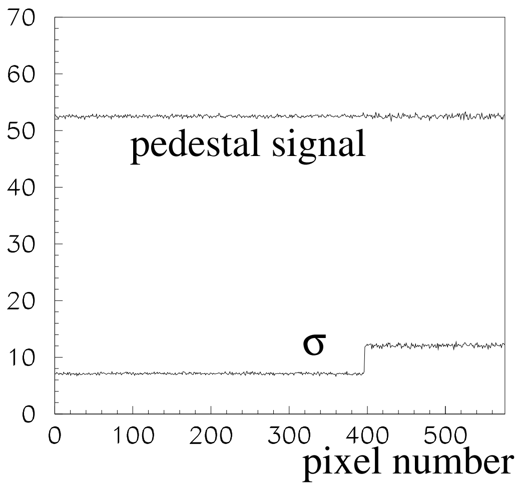


Fig.1. The average value and the standard deviation of the noise signal in each camera pixel.

The simulated images (CORSIKA+Reflector+Camera) were analyzed by the standard method and their Hillas parameters were determined for showers which fulfill the trigger condition. To use the "standard" image cleaning" described by two well known factors (values 3.0 and 2.5) were used. The average pedestal and its σ were determined and they are shown in Fig.1. For the signal from each pixel we used the sum of 5 FADC channels (staring from the third), thus the pedestal was estimated using the other subsequent five channels (from 10 to 14).

2 Energy spectra of registered events

The most significant difference between North and East showers triggered the MAGIC telescope is clearly seen in the Fig.2 where their energy distributions are presented.

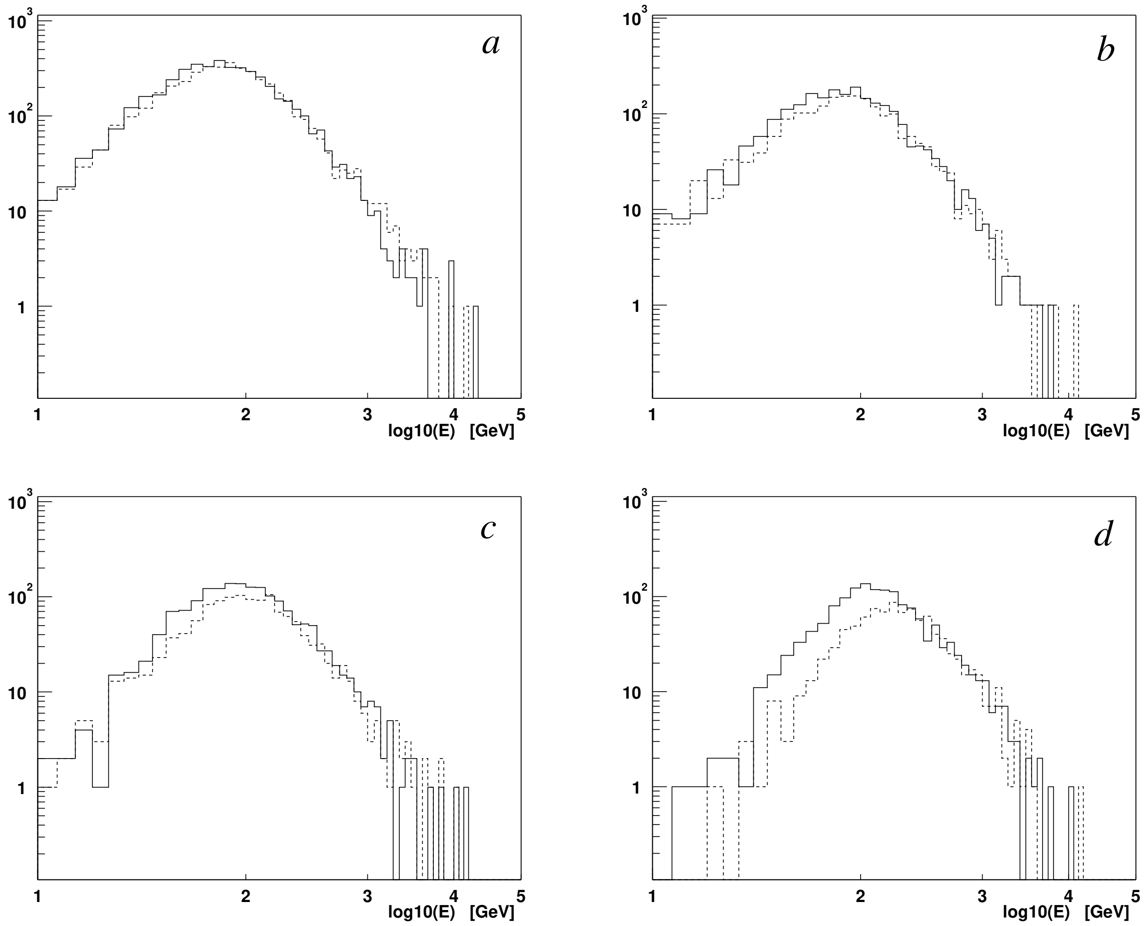


Fig.2. Energy distribution of events recorded by the MAGIC telescope at zenith angle of 10°, 20°, 30° and about 40° (*a*, *b*, *c*, and *d*, respectively) for North (solid lines) and East (dashed) telescope azimuthal angle.

Table. Fraction of events which fulfill trigger requirements for different trigger discrimination levels in each simulated shower sample.

		trigger level				
zenith	azimuth	4.0	4.3	4.5	4.7	5.0
10	North	**0.0113**				
	East	0.0106				
20	North	0.0110	**0.0094**			
	East	0.0094				
30	North	0.0167		**0.0128**	0.0116	
	East	0.0127				
≈ 40	North	0.0145		0.0110	**0.0100**	0.0087
	East	0.0095				

The clear excess of small showers from the North is seen. It could be expected as an effect of the fact that the East showers are spread slightly more because of larger perpendicular B component seen at this direction, thus there is harder for them to fulfill the given trigger condition. In the Table fractions of registered events (showers were simulated from the power-law the energy starting at 10 GeV with spectral index of 2.6) in each case are given. (Fractions for different zenith angles should not be compared directly, because some conditions of simulation calculations are different, e.g., maximal radius of shower axis impact circle.)

The change (increase) of the trigger discrimination level for North showers reduces the fraction of registered events. These numbers are given also in the Table. To see how this effect different energies of simulated showers the whole spectra should be compared in each case. This is done in Fig.3.

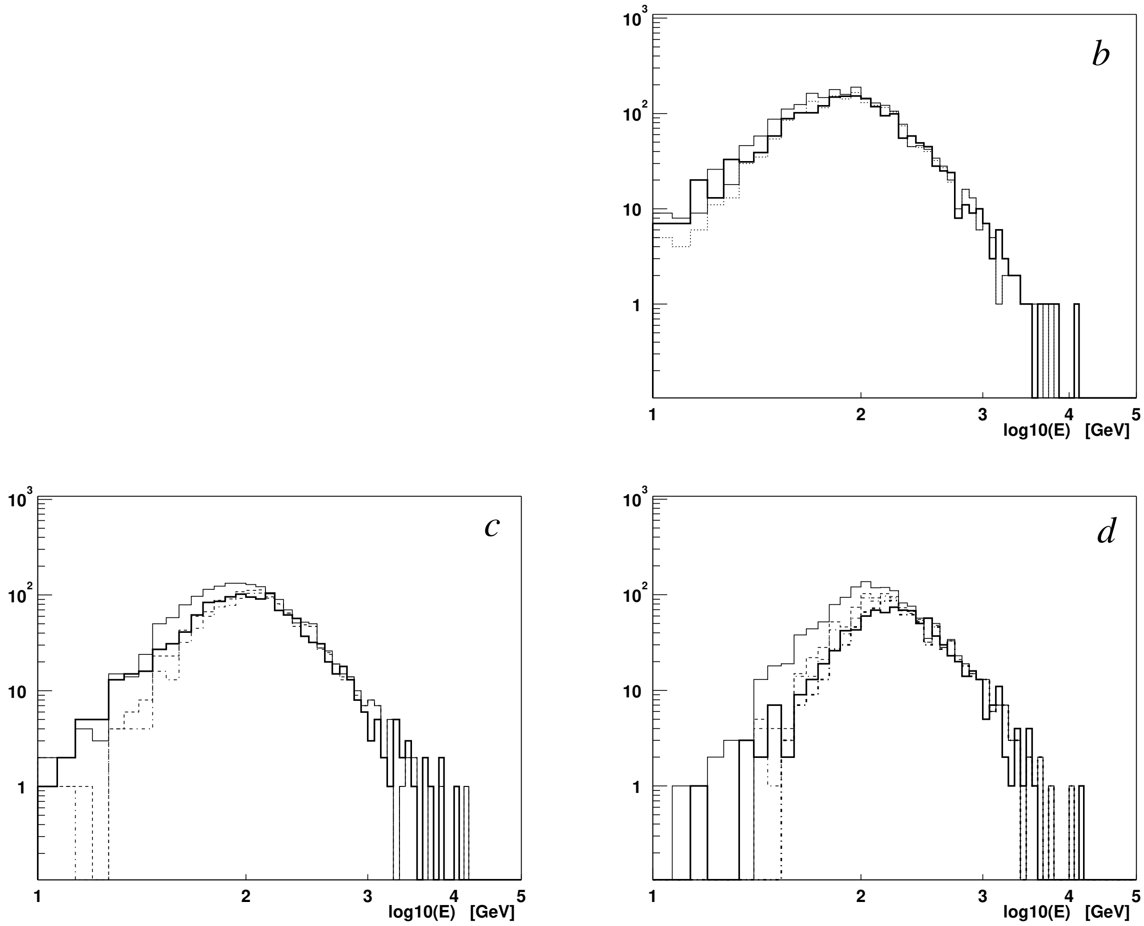
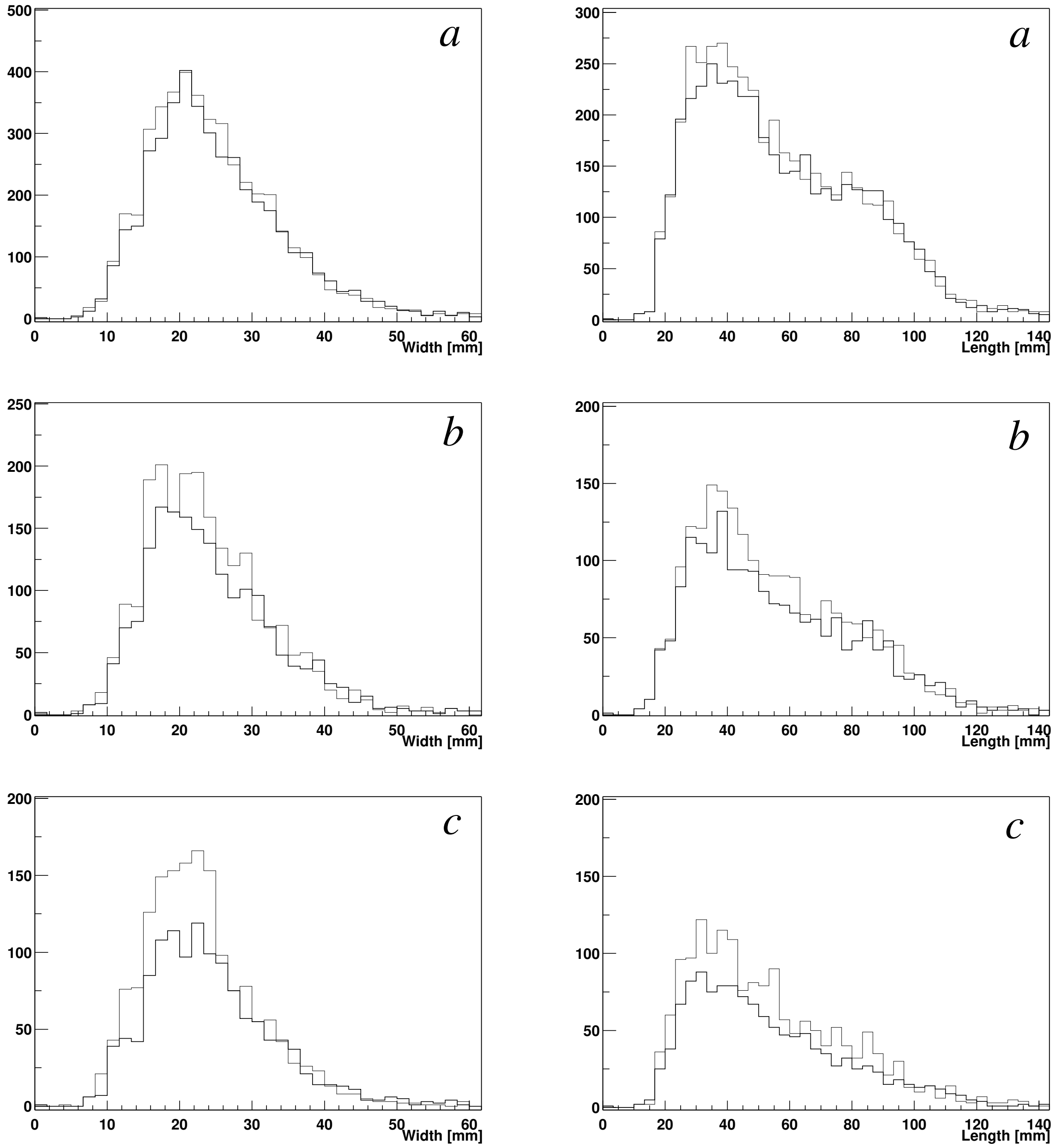


Fig.3. Energy distribution of events recorded by the MAGIC telescope at zenith angle of 20°, 30° and about 43° (b, c, and d) for North (thin lines) and East (thick solid lines) telescope azimuthal angle. The trigger discrimination level is 4.0 for East events and for North events 4.0 (solid line) 4.3 (dotted), 4.5 (dashed) 4.7 (dot-dashed) and 5.0 (thick dot-dashed lines).

To some accuracy, it can be said that, the distributions for North event energies and for discrimination levels shown by bold numbers in the Table I are quite close to the East event distributions with standard (4.0) level.

3 Image parameter distributions

The comparison of distributions of image parameters from the North and East shower samples with the standard trigger threshold (4.0 phes) shows clearly big differences. Some distributions (for the LENGTH and the WIDTH parameters) are shown in Fig.4, other looks similar.



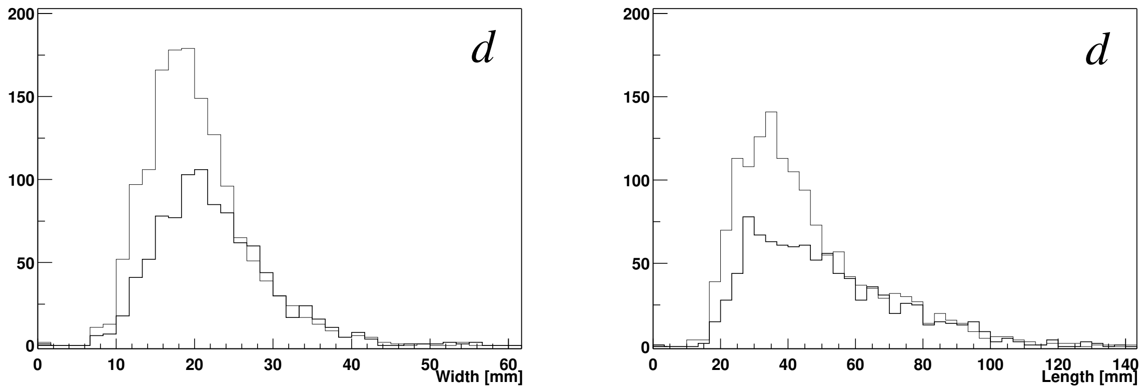
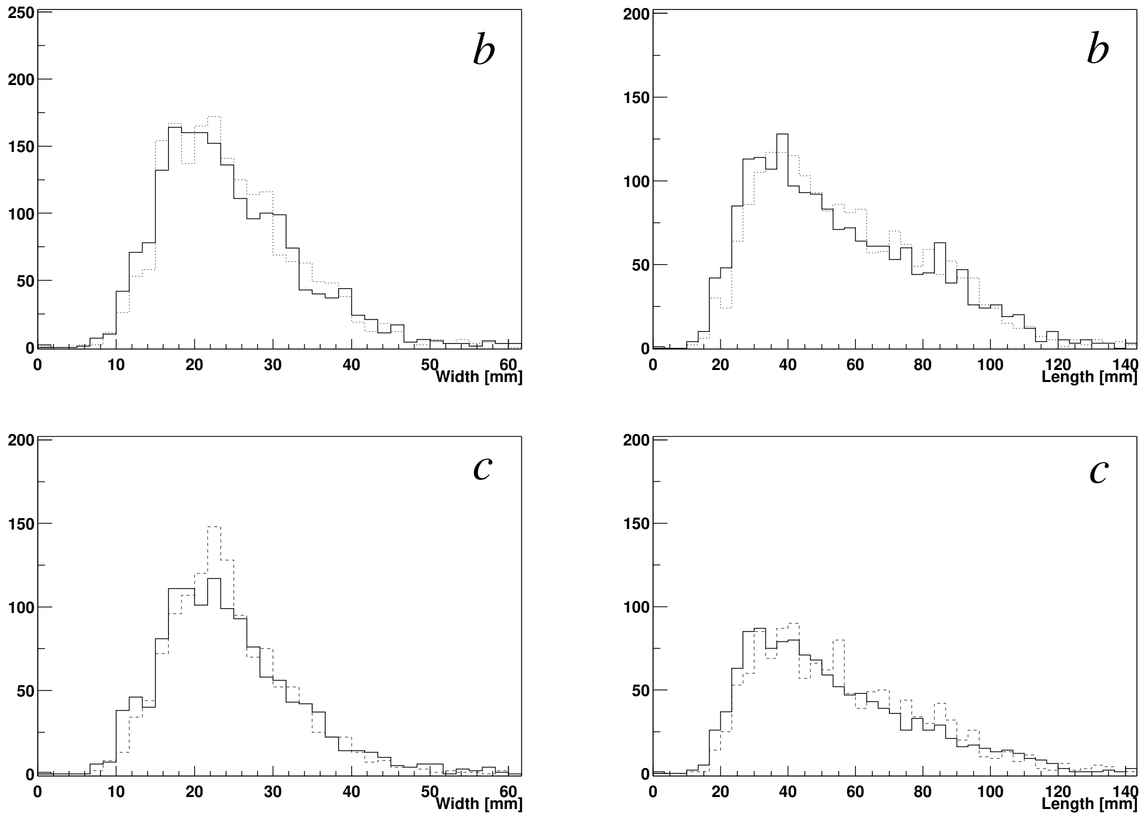


Fig.4 Distributions of the WIDTH (left plots) and the LENGTH (right) parameters of events recorded at different zenith angles (lines as in Fig.2).

As it is shown above, samples of registered events with correctly chosen trigger discrimination levels consists events of (about) the same energies. It is interesting to see image parameter distributions in such samples. They are presented in Fig.5.



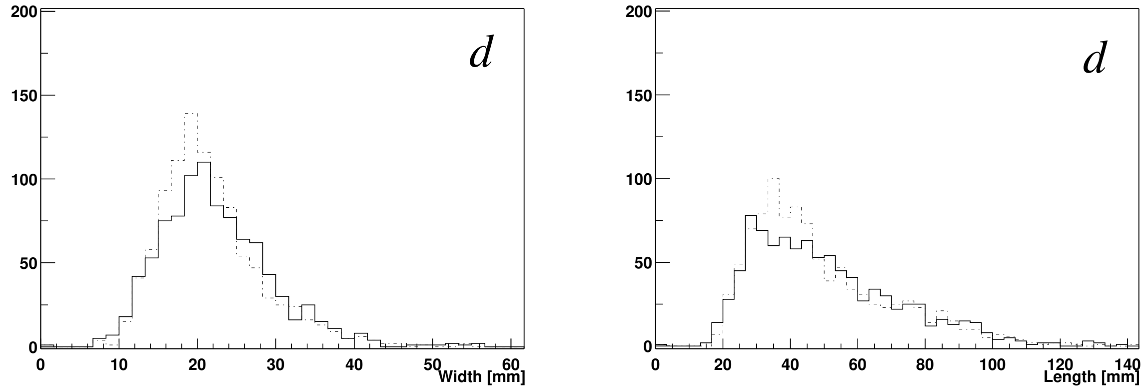
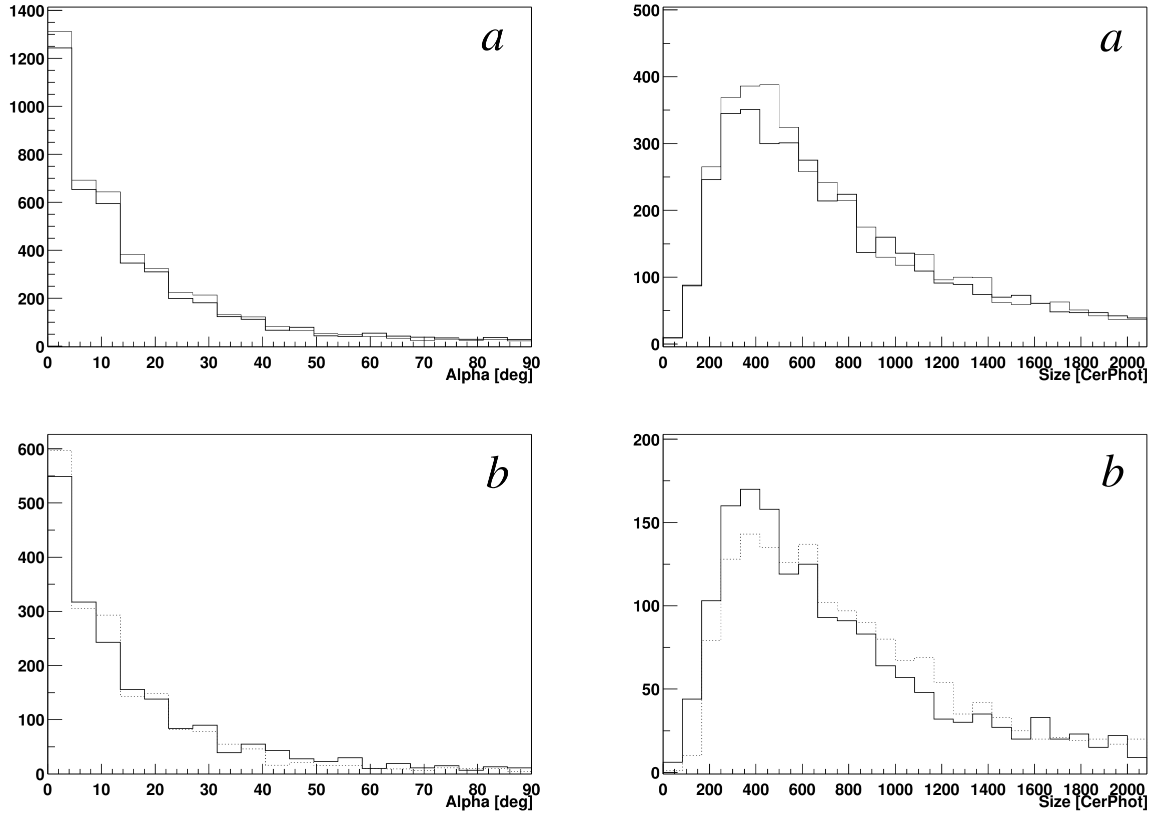


Fig.5a Distributions of the WIDTH (left plots) and LENGTH (right) parameters of events with different zenith angles (shown as in Fig.3).



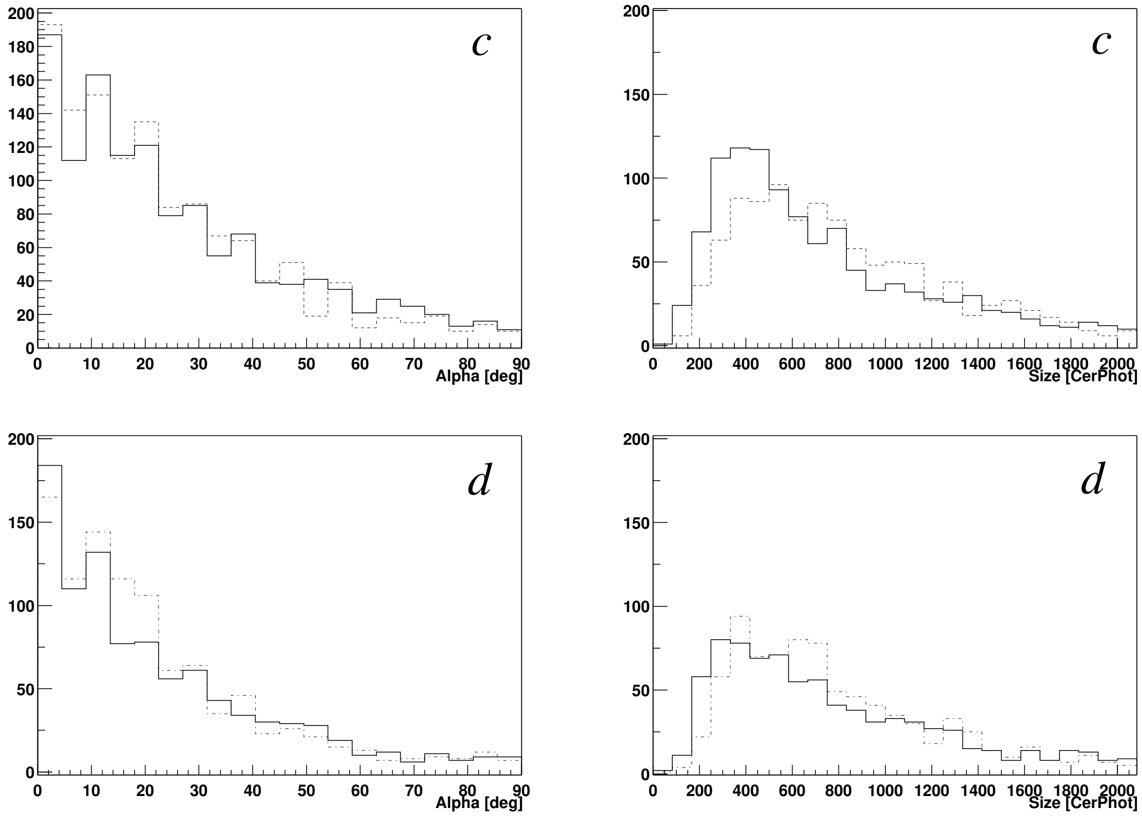


Fig.5b Distributions of the Alpha (left plots) and Size (right) parameters (as in Fig.5a).

4 Summary

The effect of the Earth magnetic field is, as can be expected, the widening of the Čerenkov photon angles distributions. The bigger spread makes triggering conditions harder to fulfill for small showers (photons which could hit one pixel are distributed around). It seems that the registration threshold is the main (if not the only one important) effect. However, the effect is quite significant as one looks at the event rate as a function of an azimuth angle and it has to be taken into account in, e.g., effective area and energy threshold calculations.

We have shown that the carefully chosen trigger discrimination level for North events can compensate the loss of East events and not only in the total number of registered events (which is obvious) but also in the whole shape of the energy spectrum of observed showers.

We have also shown, that such change of trigger conditions lead to satisfactory similarity of distributions of the image parameters of registered events. Respective North and East distributions do not exactly coincide, of course. The differences seen in presented graphs are quite small and so irregular (that could be even a result of the Monte Carlo method) that any attempts to find some simple correction factors are rather hopeless.

When analyzing simulated showers it is easy to tune the trigger level, but in real case it seems impossible, so the procedure of the "artificial off-line trigger" should be invented. It could use the actual trigger logic, but it is not necessary. We hope that it should eventually give "North-East asymmetry" correction better than the one discussed in this report.

What is also important, we believe that results obtained give some confidence for the γ/hadron separation procedures, that they should work well in once developed form for any azimuthal angle.