29th International Cosmic Ray Conference Pune (2005) **9**, 275-278

Investigation of several trigger systems and selection for different cosmic ray primaries for HECRE experiment proposal

A. Mishev[a] and J. Stamenov[a]
(a) Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, 72, Tsarigradsko chaussee, Sofia 1284, Bulgaria
Presenter: A. Mishev (mishev@inrne.bas.bg), bul-mishev-A-abs3-he24-poster

The previously obtained approximation of lateral distribution of atmospheric Cherenkov light in EAS for primary protons gives the possibility for fast Monte Carlo simulation with large statistics of the detector response and thus estimation of detector efficiency. Several billions of events are simulated taking into account inclined showers, the quantum efficiency of the photomultiplier, axis distribution etc. Several trigger condition for HECRE experiment are proposed and studied. The constant efficiency registration for different primaries is investigated.

1. Introduction

In the field of astroparticle physics the estimation of primary cosmic ray composition and energy spectrum are the main problem to resolve. From the point of view of future experiment as HECRE [1] it is very important to estimate the detector array efficiency and to propose appropriate triggers in attempt to reduce as much as possible the background events and the experimental noise as well. Possible solution is based on Monte Carlo technique i.e. the simulation of the response of given detector array and applying some cuts and constraints to estimate afterwards the registration efficiency. Nonetheless the Monte Carlo technique gives the possibility to propose one or several possible triggers of the detector array and studying their performances to choose the best one. The previously obtained approximation [2] of lateral distribution of atmospheric Cherenkov light densities in extensive air shower for different primaries gives the possibility of fast Monte Carlo simulation [3].

2. Discussion

The HECRE [1] experimental proposal represents several detectors including Cherenkov array. The Cherenkov detector array is similar to the AIROBICC [4] detector array, so 49 detectors in uniform set. All detectors are capable to measure the Cherenkov light density and to measure the relative arrival time, which permits to determine the arrival angle for individual shower. The scientific goals of this experiment can be divided in ground based gamma ray astronomy in the energy range of the gap [5] between space-borne and ground based experiments and study of the energy spectrum and mass composition of primary cosmic ray in the region around the “knee” [6]. It is desirable to make measurements of the different primaries with constant efficiency in attempt to make a correct analysis of the measured events. It is clear that for large statistics we need a Monte Carlo simulation of the detector response. One of the possibilities is to use the Corsika [7] code. On the other hand this code is very CPU time consuming. Thus we need a fast Monte Carlo procedure. Therefore using a previously obtained approximation of the lateral distribution [2] of the atmospheric Cherenkov light flux densities in EAS a code for fast Monte Carlo simulation is developed. The simulations are carried out according the steep energy spectrum and uniform shower axis distribution. For simplicity of the problem only vertical showers are simulated. The simulated events are $5x10^6$ and afterwards each proposed trigger is studied assuming different thresholds.

3. Results

The simulated shower axes are up to 300m from centre of the detector array, the statistical fluctuations are taken into account. Additionally the quantum efficiency of the photomultiplier is taken into account and it is assumed to 0.15. We assume a threshold of 100 photoelectrons. On the experimental point of view and taking into account some previous experience this threshold seems to be reasonable. The proposed trigger condition is presented in Figure. 1. With black squares are presented the detectors included in the groups for master conditions. The detectors not included in the trigger, used only for measuring the signal are represented with open squares. The trigger condition is as follows: an event is registered if the signal is above the threshold in one central group of detectors and at the same time in all the four additional groups. In each group we have four detectors. The trigger condition for each group is each detector signal in the group should be above the chosen threshold. In the conditions above the obtained registration efficiency is 0.995. The additional analysis with larger statistics confirms this result. The not registered events are divided in several cases: events with huge fluctuations in the region around the threshold; events outside the detector array and combination of both cases. Taking into account the obtained efficiency registration it is not necessary to study the registration efficiency as a function, of the energy of the primary and the distance from the centre of detector array. The trigger conditions for other primaries are quantitative and are not a topic of detailed study. Anyway the expected results are similar taking into account the fact that the integral densities are with similar values. This result is not a surprise because the big densities of Cherenkov photons up to few hundred meters from the shower axis in this energy range [8]. It is obvious the decreasing of the threshold leads to increasing of the registration efficiency. At the same time a big decreasing of the threshold is not reasonable because the expected experimental difficulties.

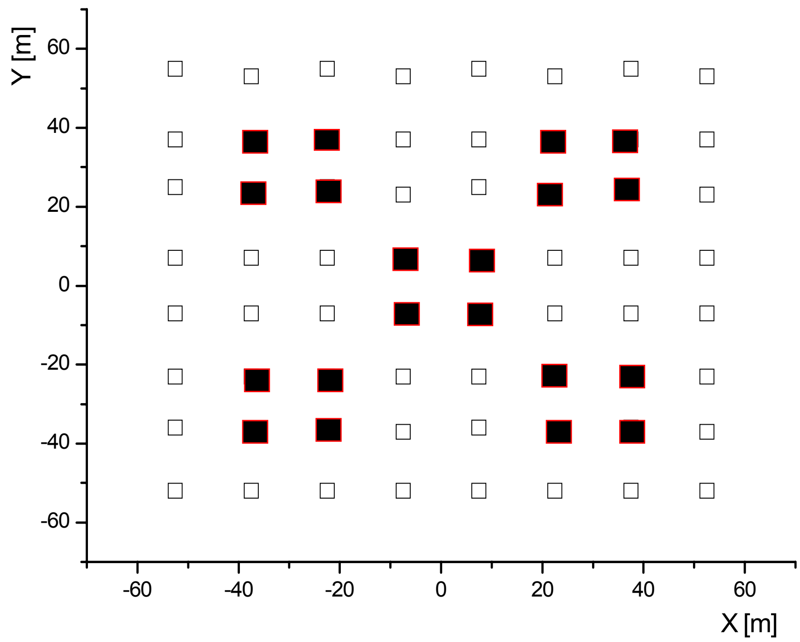

Figure 1. Trigger detectors and conditions for HECRE detector array.

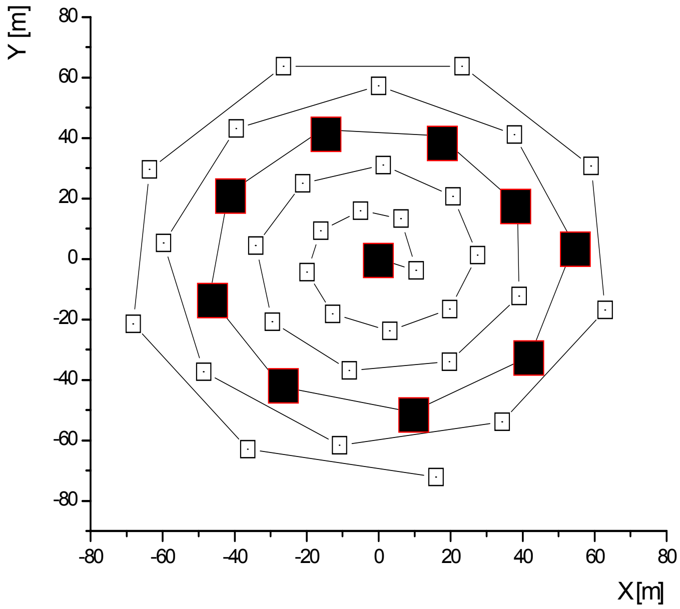

Figure 2. Trigger detectors and conditions for SPIRAL detector array.

In the case of 1000 photoelectrons threshold the obtained registration efficiency decrease till 0.754. This threshold seems to be reasonable in the energy range around the "knee" especially for mass composition studies. An additional study is carried out towards to investigate the possibilities of the array for detection of relatively low densities. This is very important for some studies in the energy range below 10^{13} eV and in the region of the gap between space-borne and ground based gamma ray astronomy. A threshold below 10 photoelectrons will be very difficult for exploitation in an experiment because the usual level of electronic noise and night skylight. In this case one simulate only proton events with threshold energy of 10^{12} eV. The obtained registration efficiency is 0.69. As was expected the peripheral events are with low registration efficiency, practically the events, which are outside of the detector array, are not registered. Obviously decreasing the threshold is possible to detect and measure lower energies. Additional study is carried out for SPIRAL detector array [2]. The SPIRAL detector array is larger comparing to HECRE. An additional difficulty is the asymmetry of this detector array. Obviously one needs at least one detector on the centre of the array and several detectors displaced at equal if possible distances from centre of the detector array. In this case the trigger condition is as follows: the coincidence of the central detector of the array and 9 other detectors shown in Figure.2. In this case the threshold of 100 photoelectrons is assumed, the simulated events are in the energy range 10^{13}-10^{16} eV. The obtained efficiency is in the same order i.e. the registration efficiency is 0.99. This efficiency decrease fast in function of the assumed threshold till 0.55 in the case of 1000 photoelectrons. Similar result is obtained in mentioned above conditions for ground based gamma ray astronomy. Thus as was expected the SPIRAL detector array is less efficient in the range of the low energies. One possibility to solve this problem is a more compact trigger condition, which is not topic of this study. The disadvantage in this case is the smaller effective area of the detector array. The study of events with very low densities of Cherenkov photons and events with axes large outside the detector array is not topic of this study and will be performed in the future.

3. Conclusions

Several trigger conditions are investigated for HECRE experimental proposal in different energy ranges of interest. This permits to propose an appropriate trigger for gamma ray studies in the energy range below the TeV and at the same time the same trigger for energy range of 10^{15} eV. An additional study of SPIRAL detector array is also carried out and the trigger condition is proposed. Moreover the proposed trigger is a little bit more effective, which is not trivial for asymmetric detector array. In the future more detailed study is necessary the aim is to investigate the proposed trigger conditions in the energy range around the TeV energies. One of the goals is to propose a trigger with larger efficiency for gamma quanta and with smaller efficiency for hadronic primaries. This will permit to reduce additionally the expected background events, but will results on more difficult event analysis and reconstruction. Additional study for inclined showers and obtaining the registration efficiency as a function of the energy and the type of the incoming primary is also necessary.

4. Acknowledgements

We warmly acknowledge our colleagues from INRNE for the fruitful discussions during this study.

References

[1] O. Saavedra et al.,. Il Nuovo Cimento C vol. 24, 497 (2001)
[2] A. Mishev et al. Nucl.Instrum.Meth. A530, 359 (2004)
S. Mavrodiev et al., 28th ICRC, Tsukuba (2003), 163
[3] A. Mishev et al., 29th ICRC, Pune (2005)
[4] A. Karle et al., Astropart. Phys. 3, 321, (1995)
[5] A. Mishev et al., arXiv astro-ph/0410118 (2004)
A. Mishev et al,. To appear in Journal of Modern Physics A (2005)
[6] S. Mavrodiev et al,. arXiv: astro-ph/0310651 (2003)
[7] D. Heck et al., Report FZKA 6019 Forschungszentrum Karlsruhe (1998)
[8] A. Mishev et al., 28th ICRC, Tsukuba (2003) 247