Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008
Vol. 3 (OG part 2), pages 1289–1292

30TH INTERNATIONAL COSMIC RAY CONFERENCE

ICRC'07 Mérida, México

Kartalska field telescope - project proposal for ground based gamma astronomy

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Abstract: The Kartalska filed ground based telescope for gamma astronomy is presented. It represents wave front sampling Cherenkov telescope of 7 detectors. The detector design is described, the reconstruction strategy and detector prototype. The scientific potential of telescope is discussed.

Introduction

The field of cosmic ray studies is part of astroparticle physics is connected with both particle physics and astrophysics. This new and interesting field is rapidly extending during the last years after the discovery and observation of phenomena such as supernova remnants, active galactic nuclei, gamma ray bursts, which have significant impact to our knowledge of the universe. At the same time there are still several very important unsolved problems connected with the origin and acceleration mechanisms of primary cosmic ray flux. Basically the origin of primary cosmic ray is a central unresolved problem in astroparticle physics. It is generally regarded that the bulk of cosmic rays originate from the Galaxy and the part below the "knee" comes from Galactic supernovae, the particles being accelerated by the shocks in the supernovae remnants. At higher energies it exist problems connected with the conventional supernova remnant, the bulk of the sources have a natural limit of a few tens of PeV (for Iron nuclei). Thus the question of the particles above this limit is open. An interesting problem is the existence of the "knee" i.e. the observed change of the slope of the primary cosmic ray spectrum. One possible explanation is based on the super nova remnants diffuse shock acceleration mechanism. Thus it is very important to study the primary cosmic ray spectrum around the "knee" in attempt to build an appropriate model concerning the origin and acceleration mechanisms of the primary cosmic ray flux. It is obvious that precise studies of spectral irregularities will provide considerable help in the search for cosmic ray origin.

Above 10^{14} eV the only possibility for cosmic ray detection and measurement is ground based i.e. the detection of one or several of the components of secondary cosmic ray. One of the most convenient techniques in cosmic ray investigation is the atmospheric Cherenkov technique i.e. the detection of the Cherenkov light in extensive air showers.

At the same time the cosmic ray studies are complementary to gamma ray astrophysics since many gamma rays are produced in processes connected with cosmic ray such as synchrotron emission as example.

Detector design

The Kartalska field Cherenkov ground based gamma Cherenkov telescope represents set of spherical mirrors working in a coincidence regime [1]. The Kartalska field telescope is a time and angle integrating device. The set is hexagonal with one central mirror and it is similar to HOTOVO wide angle telescope [2]. The main receiver is a 1.5m diameter spherical mirror with focal length of 1m and matrix of 5 photomultipliers Fig. 1. The main difference is the integrating angle of Kartalska field telescope which is smaller and not exceeds 5 degrees. The trigger condition is very similar central detector in coincidence with at least 3 others. Thus the assure registration efficiency of about 90% in the energy region around 1 TeV according the initial design [1].

The prototype mirrors Fig. 2 are the same as the Ice Lake experiment [3] with the difference in main receiver. In Kartalska field we will use a matrix of 5 photomultipliers instead of one big photomultiplier.

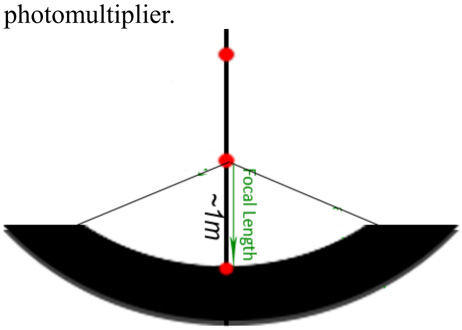

Figure 1: A mirror for Cherenkov telescope

In this case the use of spherical mirror is not crucial according the estimations. Even of the case of significant spherical aberrations, the important information is obtained from measure of the Cherenkov light densities.

Figure 2: Ice Lake experiment mirrors - prototype for Kartalska filed gamma telescope

Reconstruction strategy and detector response

The detection of the air Cherenkov light at ground level using an array of telescopes or photomultipliers is a powerful tool for ground based gamma astronomy and the mass composition studies of primary cosmic rays. Such types of telescopes are based on time and angle integration of Cherenkov light flux at the observation level. Obviously one needs a detailed and precise data concerning the lateral distribution of the atmospheric Cherenkov light at ground level, in one hand tom estimate the detector performances and on the other hand to build a reconstruction strategy. On the basis of simulation with CORSIKA 6 code [4] with GHEISHA [5] and QGSJET [6] models the lateral distribution of Cherenkov light flux is obtained fro primary protons Fig. 3 and gamma quanta Fig. 4 at Kartalska filed observation level of 1410 m above sea level (875 g/cm^2).

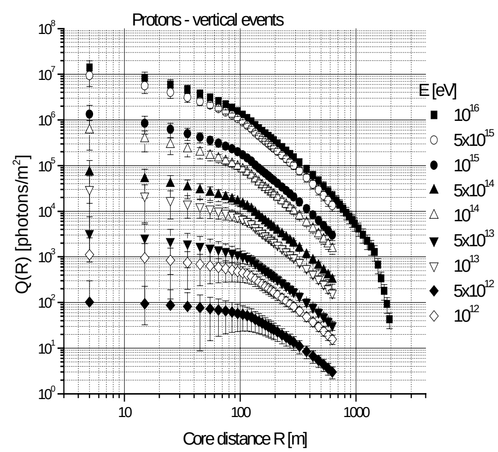

Figure 3: Lateral distribution of Cherenkov light flux initiated by primary protons at 875 g/cm^2

The reconstruction of the events is carried out on the basis of previously proposed method for ground based gamma astronomy [7]. The final aim is to propose approximation with one function (in this case non linear fit), the same for each distribution. Thus it is possible to fit all the simulated lateral distribution of Cherenkov light initiated by different primaries using different parameter values of the proposed model function.

Afterwards the distinction between the different primaries is carried out using the differences of the model parameters and the difference of the χ^2 of the final fit. The energy estimation is obtained by simple integration of the reconstructed lateral distribution and one of the model parameters connected with the type of the initial particle.
During the reconstruction procedure i.e. the solution of the inverse problem all model parameters are used in the iterative process. This permits to find more precise solution in every iteration step comparing with the previous step and the avoid a wrong reconstruction. The detailed study of the model parameters as a function of the energy and the type of the initiated primary is carried out.

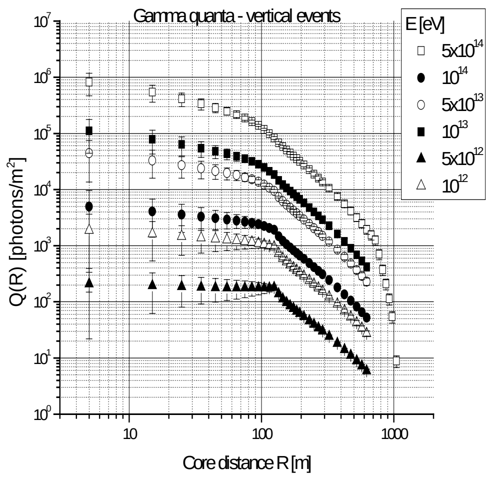

Figure 4: Lateral distribution of Cherenkov light flux initiated by primary gamma quanta at 875 g/cm^2

The proposed parameterization is [8]

$$Q(R)=\frac{\sigma e^{a} e^{-\left[\frac{R}{\gamma}+\frac{R-r_0}{\gamma}+\left(\frac{R}{\gamma}\right)^2+\left(\frac{R-r_0}{\gamma}\right)^2\right]}}{\gamma\left[\left(\frac{R}{\gamma}\right)^2+\left(\frac{R-r_0}{\gamma}\right)^2+\frac{R\sigma^2}{\gamma}\right]}$$

This parameterization permits using very similar procedure to investigate the mass composition of primary cosmic ray in the energy range around the "knee". The method is described in [9, 10, 11]. The crucial point is the observed differences in lateral distributions between hadronic primaries and gamma quanta Fig. 5, which permits the gamma hadronic separation and the observed differences between lateral distributions of proton and iron induced showers Fig. 6.

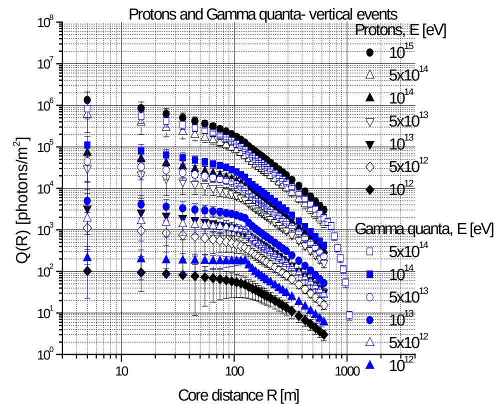

Figure 5: Differences between lateral distributions of Cherenkov light flux initiated by primary protons and gamma quanta at 875 g/cm^2

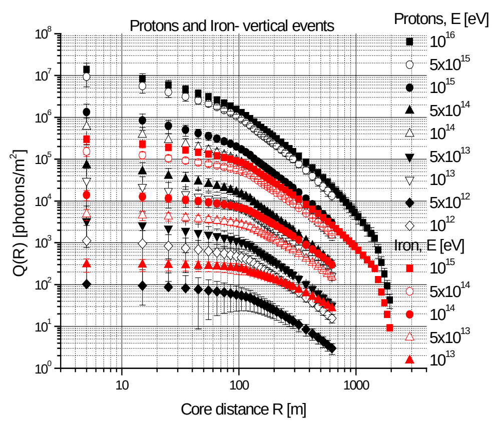

Figure 6: Differences between lateral distributions of Cherenkov light flux initiated by primary protons and iron nuclei at 875 g/cm^2

Several preliminary measurements with two mirrors are carried out by E. Malamova at Alomar observatory [12]. On the basis of the accumulated experience and additional simulations for the trigger condition (coincidence of central detector with at least 3 others) is estimated the energy threshold to 10^{13} eV.

Conclusion

The Kartalska filed project proposal is described. The scientific potential of the telescope is discussed. The reconstruction strategy is presented.

Acknowledgements

This study is supported under NATO grant EAP.RIG. 981843. We warmly acknowledge all our colleagues from BEO Moussala.

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