Proceedings of ICRC 2001: 608 © Copernicus Gesellschaft 2001

ICRC 2001

Simulation of the response of the GAMMA array to the EAS particle components

M. Z. Zazyan[1], **R. M. Martirosov**[1], **and J. Procureur**[2]

[1]Yerevan Physics Institute, Alikhanian Brothers 2, 375036 Yerevan, Armenia
[2]Centre d'Etudes Nuclearires de Bordeaux-Gradignan, Le Haut Vigneau B.P.120, 33175 Gradignan Cedex, France

Abstract. Energy deposits of different kinds of shower particles in e/γ-detectors of the GAMMA array at Mt.Aragats (3200m, Armenia) are obtained by the simulations with CORSIKA event generator and ARES detector response program. With these simulations photon contribution to the densities of charged particles is derived.

1 Introduction

The lateral distribution of electrons in extensive air showers (EAS) is widely used in event reconstruction, aiming to obtain information about primary particle. An integration over the total range of core distance of the lateral distribution function (LDF) results in the shower size, i.e. total number of particles. An estimates of the core position and the age parameter are also made by the use of LDF. The knowledge of the correct LDF is therefore of general importance in EAS research.

In the case of the GAMMA experiment data the lateral distribution of electrons is very well approximated by Nishimura-Kamata-Greisen (NKG) function (Eganov et al., 1999). The experimentally registered densities, however, correspond to some mixture of different tipes of particles and the detector signals have to be corrected for expected contributions from particles other than electrons.

Detailed Monte-Calro simulations of both the air shower development in the atmosphere and the detector response are needed to understand the measured distributions and to derive the lateral distribution of the EAS electrons.

2 Experimental Setup

The surface array of the GAMMA experiment is intended to register the EAS electromagnetic component. It consists of 25 detector huts distributed over the full area of $\approx 1.5 \cdot 10^4$ m^2. Each hut contains three plastic scintillation detectors (e/γ-detectors) of an effective area of 1 m^2 and a thickness of 5 cm. The density of the plastic scintillator is 1.1 g/cm^3 The detectors are built into aluminium pyramid-shaped housings.

The GAMMA array has been described in more detail elsewhere (Eganov et al., 2000).

Correspondence to: M. Z. Zazyan
(mary@jerewan1.yerphi.am)

3 Simulations

The simulated air shower events were produced with the CORSIKA code (V 5.62) (Heck et al., 1998) with the interaction model QGSJET (Kalmykov et al., 1997) and the EGS4 option (Nelson et al., 1985) for e/γ component. 300 proton induced showers of the energy of 10^{15} eV and zenith angle of 20° were generated for the observation level of Mt. Aragats.

EAS particles thresholds are - 300 MeV for hadrons and muons and 3MeV for electrons and photons. It means that the output of CORSIKA on observation level contains particles with energies above these values.

We have studied the detectors response by using a modified version of ARES program (Haungs et al., 1999) based on GEANT package (CERN, 1993). In this version the surface detectors of GAMMA array are added. The shower core positions are varying within a square of $50m \times 50m$ with the center in the middle of the calorimeter.

4 Photons contribution to the detector signal

The simulation allows to examine the detector response for each type of EAS particle.

Simulated energy deposits as a function of a distance from the shower core are presented in Figure 1 for different particles.

As expected, electrons and photons deposit a large amount of energy in the e/γ-detectors, while muons and hadrons contribute a small background. Photons contribution to the detector signal can be described by the parameters $K = \epsilon(e +$

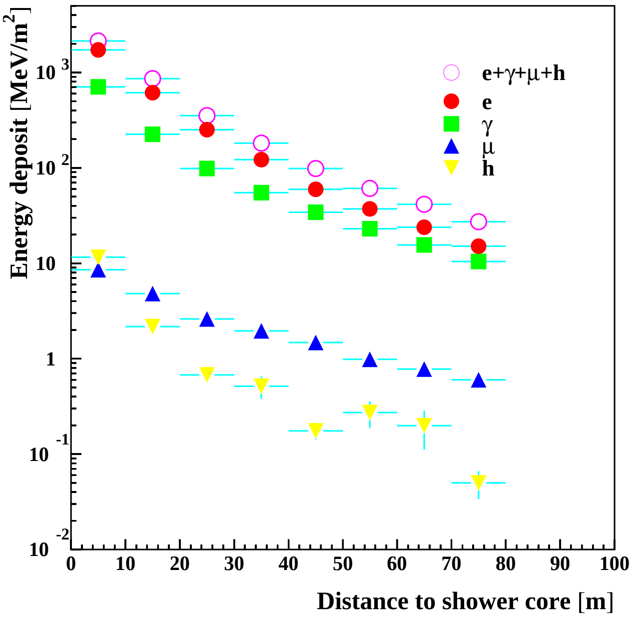

Fig. 1. Simulated energy deposit per m^2 in e/γ-detectors as a function of the distance to the shower core.

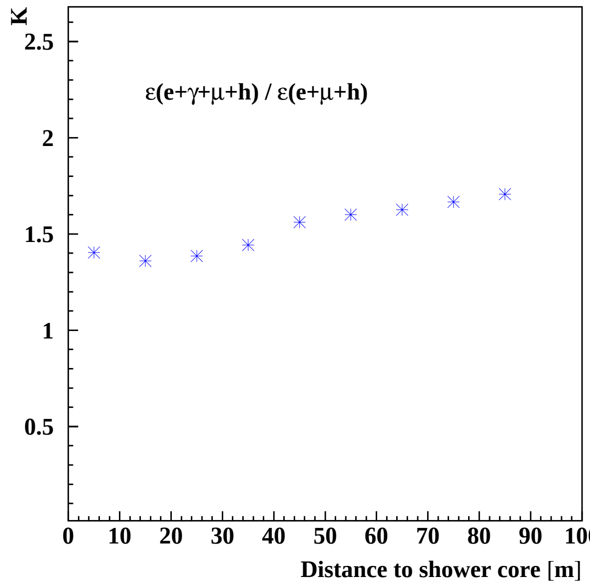

Fig. 2. The ratio of the total energy deposit to the energy deposit from charged EAS particles as a function of the distance to the shower core.

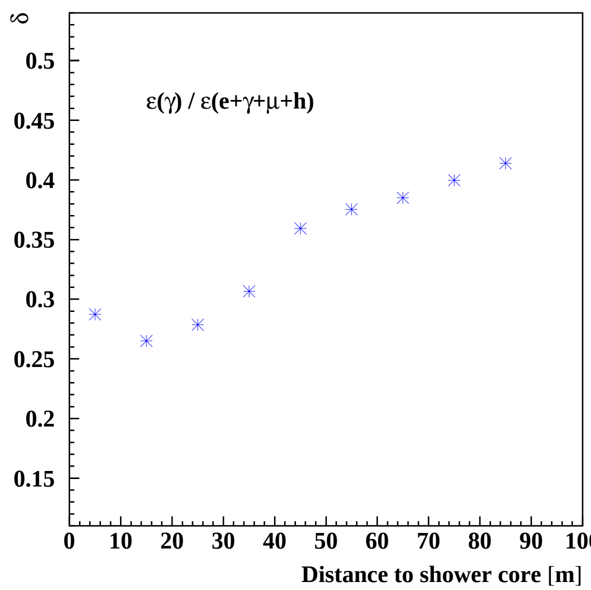

Fig. 3. The ratio of energy deposit from EAS photons to the total energy deposit as a function of the distance to the shower core.

$\gamma+\mu+h)/\epsilon(e+\mu+h)$ or $\delta = \epsilon(\gamma)/\epsilon(e+\gamma+\mu+h)$, where $\epsilon(e+\gamma+\mu+h)$ is the energy deposit from all EAS particles, $\epsilon(e+\mu+h)$ - from particles excepting photons, and $\epsilon(\gamma)$ - the energy deposit from EAS photons.

In different experiments the different behaviour of these parameters is used. Some of them obtain the smooth rise of photons contribution to the measured density with the distance to the shower core ((Weber, 1997) for see level, KASCADE), while others consider that it is decreasing and practically disappearing at 100m ((Blokhin et al., 1999) for 3200m, MAKET-ANI). In the case of GAMMA experiment the photons contribution to the measured number of charged particles is considered to be constant from 5m to 100m (Eganov et al., 2000). The GAMMA data have been processed for the two last cases to study the influence of K on the measured EAS features. The difference in the shower size N_e is no more than 20%, but the average age parameter S is different by about 0.16. So it is very important to know the real behaviour of K.

For solving this problem the dependences of K and δ from the core distance were obtained from the simulated data. Figures 2 and 3 show the rise of the contribution of photons to the total energy deposition with the distance from the shower core.

5 Energy threshold of electrons for CORSIKA simulation

Usually to compare CORSIKA simulation results with the data of GAMMA experiment the energy threshold of 9.5 MeV for EAS electromagnetic component in NKG approximation is used (Eganov et al., 2000).

This value corresponds to the minimum energy of the single relativistic particle capable to generate a signal in the used scintillation detectors. But the signal can be formed by several particles with the lower energies.

The lateral distributions of electrons for two energy thresholds of 3MeV and 9.5MeV were simulated using CORSIKA code (with EGS option) and ARES program.

To convert energy deposits in the detector into the particle numbers the mean energy deposit per particle was used. The distribution of the energy deposit in the detector normalized

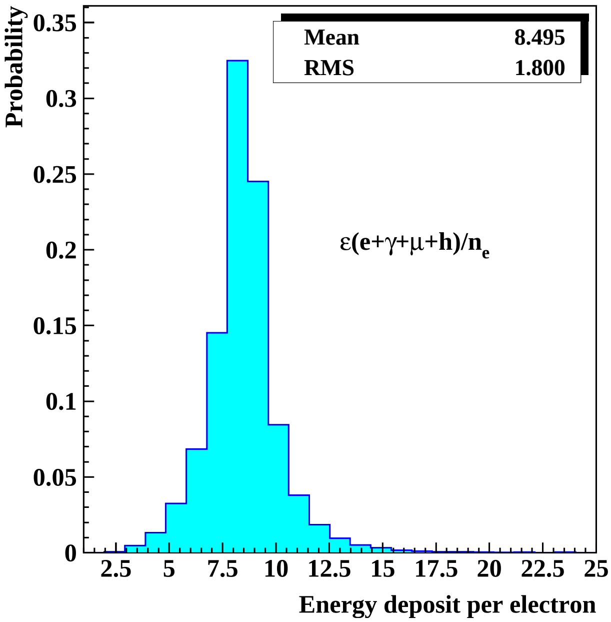

Fig. 4. The mean energy deposit per electron in e/γ-detectors.

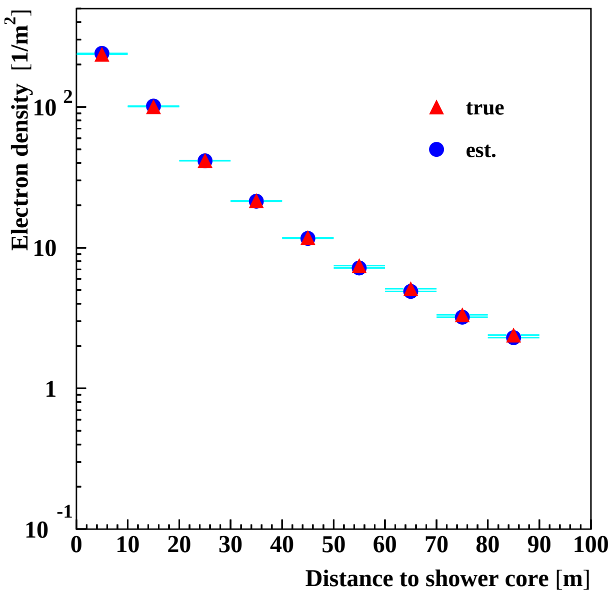

Fig. 5. The true and estimated (energy deposit/8.5MeV) electron densities in e/γ-detectors as a function of the distance to the shower core.

to the number of electrons hitting the detector is presented in Figure 4. The mean energy deposit of 8.5MeV provides a good estimate of the electron density (see fig 5).

Figure 6 shows the densities of electrons for two thresholds as a function of the distance from the shower core. The difference of these two distributions is 20 - 30 % relatively to the distribution for 3MeV. So, while using NKG option for CORSIKA simulation one needs to take into account electromagnetic particles with energies less than 9.5 MeV.

After correction of the simulated distributions for the contribution of photons the electron densities can be fitted by

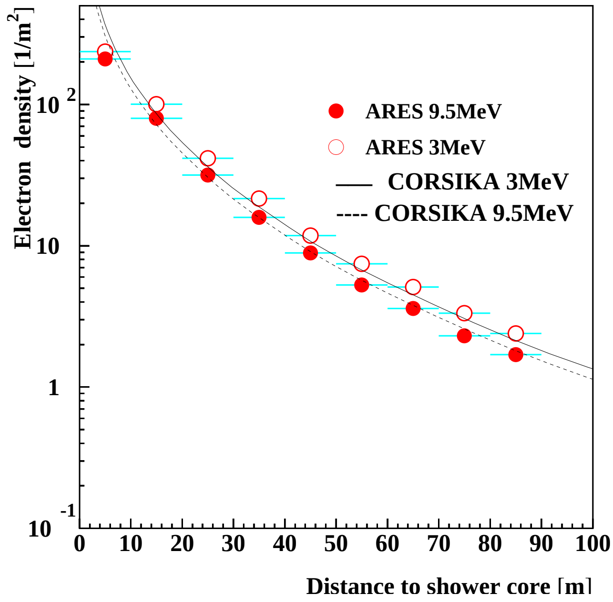

Fig. 6. Electron lateral distributions for CORSIKA (NKG option) and ARES + CORSIKA (EGS option) simulations for two energy thresholds of EAS electromagnetic component.

NKG-function. The different radius dependences of K will result in the differences in the determination of the shower size N_e and the age parameter S.

6 Conclusion

Detailed simulations were performed for interpretation of the detector signals for the GAMMA experiment.

It is shown that:

– Photons contribution to the total energy deposit is radius dependent.

– Lower energy particles as the nominal threshold of the detector for a single particle contribute to the energy deposits in a substantial way.

Due to the excessive computer times, necessary for the simulation, this study is based on a small sample of simulated showers. For the correct interpretation of the measurements a large set of simulated data for various primary particles, energies and zenith angles is needed. A careful study of detector response to the EAS particle components will be continued.

Acknowledgements. The authors are grateful to A. Haungs, A.A. Chilingarian, H. Rebel and S.V. Ter-Antonian for valuable discussions and help.

References

Eganov V.S. et al., Proc. of the Workshop ANI 99, FZKA 6472, Forschungszentrum Karlsruhe 1999, 87

Eganov V.S. et al., J. Phys; G: Nucl. Part. Phys. 26 (2000) 1355-1371

Heck D. et al., FZK-Report 6019, Forschungszentrum Karlsruhe 1998

Kalmykov N.N. et al., Nucl. Phys. 52B (1997) 17

Nelson W.R. et al., The EGS4 Code System, SLAC Report 265 (1985)

Haungs A. et al., Proc. of the Workshop ANI 99, FZKA 6472, Forschungszentrum Karlsruhe 1999, 95

GEANT : CERN Program Library Long Writeup W5013, CERN (1993)

Weber J.H., KASCADE collaboration, Proc.25th ICRC, Durban, 1997, 6, 153

Blokhin S.V. et al., Proc. of the Workshop ANI 99, FZKA 6472, Forschungszentrum Karlsruhe 1999, 111