# EAS muon distributions and primary mass composition from the GAMMA installation

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## Abstract

The phenomenological characteristics of the muon component of extensive air showers with energies $10^6-10^7$ GeV are obtained with the GAMMA installation at Mt. Aragats in Armenia, (3200m a.s.l., 700 g.cm$^{-2}$). The experimental results are compared with the simulation carried out using the CORSIKA code. A new selection parameter is analysed for an unbiased determination of the primary mass composition.

## 1. Introduction

During many years the energy spectrum and mass composition of the primary cosmic radiation at energies around the knee, ($\simeq 3\ 10^6$ GeV), were studied using different experimental techniques. In spite of that the up-to-date results are in significant disagreement for energies above the knee. There are many reasons for these discrepancies. Some of them are connected with the specificity of methods applied for the primary mass determination. The others are connected with location of experimental arrays. From this point of view because of the location of the EAS maximum development any experiment at mountain altitudes has an obvious advantage compared with those carried out at or near sea level.
In this work we present the recent results on the phenomenological characteristics of the muon component in EAS generated by primaries with energies larger than $10^5$ GeV obtained by the GAMMA array at Mt. Aragats, using a new configuration of the muon underground detectors with energy threshold $E_\mu^{thres}$=5 GeV. The experimental results are compared with simulation data obtained using the CORSIKA code (version 5.20) and QGSjet hadron interaction model, [1]. We specify that in our simulation the mixed composition is the normal: p: 40%, $\alpha$: 21%, medium nuclei (<M>=14): 14%, heavy nuclei (<M>=26): 13%, very heavy nuclei (<M>=56): 12%.

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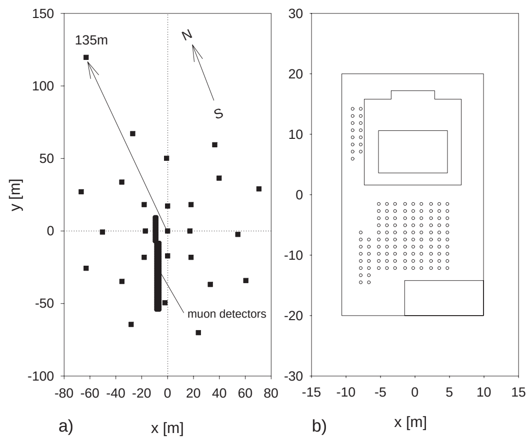


**Fig. 1.** Layout of the GAMMA installation. a) surface part b) new configuration of the underground muon detectors with $E_\mu \geq 5$ GeV

## 2. The experimental array

The GAMMA array consists of two main parts: the surface array (figure 1a), for registration of the EAS electromagnetic component and the underground muon detectors (figure 1b). For both parts scintillation detectors with effective area of 1 m$^2$ are used. The muon energy threshold is 5 GeV for the 60 underground detectors located in the hall and 2.5 GeV for the 90 detectors in the tunnel. Comparison of the EAS muon characteristics at two muon energy thresholds have enabled us to obtain the experimental muon lateral distributions for different shower sizes in the interval of distances [8, 80] meters from the shower axis. The detailed discription of the GAMMA array and results are presented in [2] and [3]. In order to increase the accuracy for estimation of the muon component characteristics the muon detector location has been modified last year: 60 scintillation detectors were added in the hall. Thereby the number of $1m^2$ muon detectors with energy threshold 5 GeV was increased up to 120. The new configuration of the muon detectors is shown in Figure 1b.

## 3. Method

Twenty years ago the Tien Shan team at mountain altitude determined the primary mass composition analyzing the fluctuations of the total muon number selecting showers by fixed values of their size $N_e$, [4]. But it is well-known, that there are still many problems with the $N_e \leftrightarrow E_0$ dependence. In order to avoid this difficulty a new approach, the so-called $\alpha(70)$-parameter, for determination of the primary energy independent of the particle mass was proposed, [5], and adapted to the GAMMA array, [6], for which the $\alpha(70) \leftrightarrow E_0$ dependence is

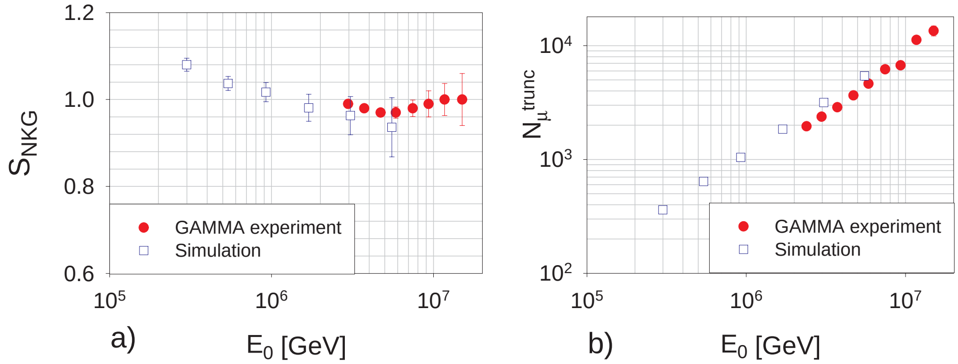


**Fig. 2.** a) $S_{NKG}$ and b) $N_\mu^{trunc}$ versus primary energy

described by: $E_0[\text{GeV}] = 4.4\ 10^3\ \alpha(70)$ - 7.5 $10^4$.
Using this new approach to select showers generated by primaries with different masses but with the same energy, we defined a new parameter with a large sensitivity to the primary mass, [7]: $\chi = N_\mu^{trunc} exp(2S_{NKG}^2)$ where $N_\mu^{trunc}$ is the muon number between 8 and 52 meters from the shower axes and $S_{NKG}$ is the shower age parameter, [8]. This parameter gives a good possibility to obtain an unbiased determination of the mass composition for given primary energies, [7].

## 4. Result

Taking into account our mass selection parameter, $\chi$, in showers picked up with fixed primary energies (it means, as specified above, with fixed values of $\alpha(70)$, [7]), it is important to compare the experimental and simulated dependences of $S_{NKG}$ and $N_\mu^{trunc}$ versus the primary energy, (figures 2a and 2b). On figure 3 the dependence of $\chi$, on the primary energy is shown. The agreement between simulation and experimental data will allow us to determine in the near future, as specified in [7], the mass composition of the primary radiation before and beyond the knee. At present this work is in a progress.

## 5. Conclusion

The present work is a continuation of what we began some years ago. The objectives are:
- to be able to select showers generated by primaries with different masses but with the same energy
- after such a shower selection to obtain unbiased basic parameters about the cosmic radiation, (energy spectrum and mass composition).

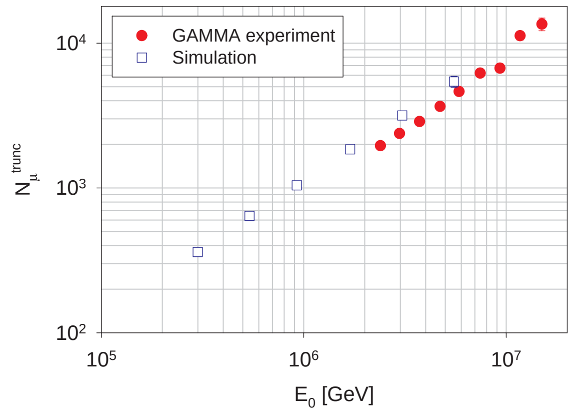


**Fig. 3.** : $N_\mu^{trunc} exp(2S_{NKG}^2)$ versus primary energy in experiment and simulation

The unbiased energy spectrum determination has been achieved,[6]. For determination of the primary mass composition for given energies, a specific parameter, $\chi = N_\mu^{trunc} exp(2S_{NKG}^2)$, sensitive to the mass, is defined in [7] and the present work confirms a good agreement between experimental and simulated data. The last step of our work is to fit the $K_\mu = \chi / < \chi >$ fluctuations with the corresponding simulated data for primaries with given masses to obtain the primary mass composition. This work is now in progress.

## 6. Acknowledgments

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## 7. References

1. D. Heck *et al.*, 1998, Kernforschungszentrum, Karlsrhue FZKA 6019
2. V.S. Eganov *et al.*, 2000, J. Phys. G: Nucl. Part. Phys., 26, 1355
3. A.P. Garyaka *et al.*, 2003, Proc. XIIth International Symposium on Very High Energy Cosmic
4. S.I. Nikolsky *et al.*, 1981, Proc. 17th I.C.R.C., Paris, 2, 129
   S.I. Nikolsky *et al.*, 1984, Zh. Eksp. Theor. Fiz., 87, 18
5. I.N. Kirov *et al.*, 1994, J. Phys. G; Nucl. Part. Phys., 20, 1515
6. A.P. Garyaka *et al.*, 2002, J. Phys. G: Nucl. Part. Phys., 28, 2317
7. A.P. Garyaka *et al.*, 2003, this conference
8. G. Cocconi, 1961, Handbuch der Physik XLVI/1, p215