ANALYSIS OF THE ELECTRON AND MUON COMPONENTS OF E.A.S. AT OBSERVATION LEVEL 700 $g.cm^{-2}$ WITH A SCALE BREAKING INTERACTION MODEL AND "GAMMAISATION" HYPOTHESIS.

J. Procureur
Laboratoire de Physique.Université de Bordeaux I
rue du Solarium
33170 Gradignan (France)

J.N. Stamenov, P.V. Stavrev, S.Z. Ushev
Institute of nuclear research and nuclear energy
Bld. Lenin 72
1184 Sofia (Bulgaria)

ABSTRACT

Scale breaking model and "gammaisation" processes for high energies give a correct description of the longitudinal development of E.A.S. From the analysis of phenomenological characteristics of E.A.S. at Tien-Shan experiment, it follows that for energies near 10^6 GeV the secondary particle multiplicity increases with energy faster than is predicted by the accepted scale breaking model.

1. Introduction We simulate the muon and electron components of extensive air showers (E.A.S.) with fixed sizes in the region 10^4-10^6 at mountain altitude. In a previous work the same authors (1) used a scale breaking model (SBM) including parameters in accordance with the results from the SPS collider and in good agreement with KNO scaling model predictions.

The SBM gives a correct description of E.A.S. at Tien-Shan level but is not able to reproduce the longitudinal development of showers.

To obtain a correct position of the maximum of E.A.S. development, we include, as was first proposed by S.I. Nikolski (2), the "gammaisation" hypothesis i.e. a larger emission of γ rays than predicted by the traditional models.

It has been shown (3) that this model gives a correct description of the longitudinal development of E.A.S.

The aim of this work is to verify if the SBM including gammaisation is compatible with the experimental muon component for showers of fixed size.

2. Method Average values of the electronic and muonic sizes, N_e and N_μ, and lateral muonic densities $\rho_\mu(r)$ are simulated by a mixed simulation model including full Monte Carlo procedures for the first interactions of hadrons and analytic approximations for deeper interactions in the atmosphere.

More precisely, the main characteristics are the following :

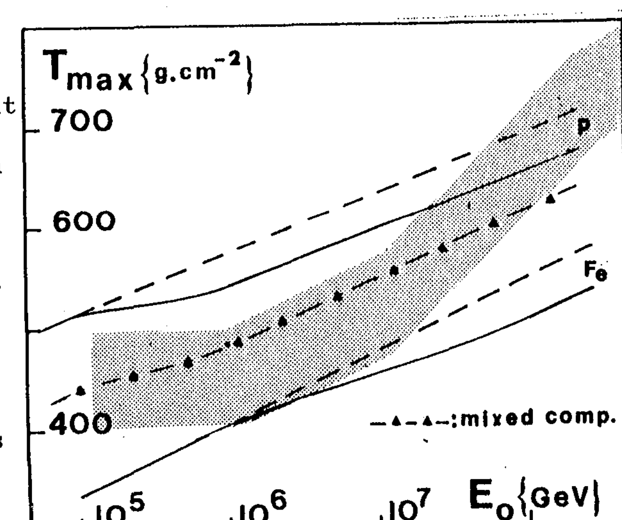
- p-air cross section increases with energy E
  $\sigma_{p-air} = 269(1.+0.05\ln(E/100))$ (mb) for $E > 100$ GeV.
  fluctuations are determined by an exponential distribution.
- average charge multiplicity : $\langle n_s \rangle = 0.57+0.584\ln s+0.127(\ln s)^2$
  fluctuations around $\langle n_s \rangle$ satisfy to the KNO scaling.
  The structure function $\psi(Z)$ is described by a gamma-k relation.
- average value of p_t increases with energy: $\langle p_t \rangle = 0.015\ln E + 0.23$
  distribution is defined by $f(p_t)dp_t = (p_t/p_0^2)\exp(-p_t/p_0)$
- the empirical rule $\langle n_\gamma \rangle = \langle n_s \rangle$ is contradicted by results from p-$\bar{p}$ collider where the estimation for $\langle a \rangle = \langle n_\gamma \rangle / \langle n_s \rangle$ is 1.4 for $\sqrt{s} = 540$ GeV. (4)
  Compilation of higher energy observations of cosmic rays jets and gamma-ray families is made in ref (2). In this publication the authors estimate that $\langle a \rangle$ could be near five for very high energy collisions.
  To take into account the "gammaisation" hypothesis we use an empirical parametrisation of the p-air interactions for E.A.S. simulations : $\langle a \rangle = 1. + 14\ln(E/10^5)$ for $E > 10^5$ GeV with the condition of saturation $\langle a \rangle \leqslant 3.$ which seems very reasonnable.
- results for showers with fixed sizes are obtained by :

$$\chi(N_o) = \int_0^\infty \chi(E)P(E,N_o)\frac{dI(E)}{dE}dE$$

,where $\chi(E)$ is the value of the observable χ for showers with fixed primary energy E. $P(E,N_o)$ is the probability for showers initiated by a given primary with energy E to obtain the fixed size N_o

To obtain a correct comparison with the experimental data we have taken into account the triggering conditions of the Tien-Shan array and the algorithm systems for the statistical data treatment.
All distorsions and statistical errors are included in a special algorithm which allows us to obtain from χ_{th} ,observable obtained from simulation using SBM, χ_p the corresponding pseudo-experimental characteristic (5).

3. Results



As shown in ref (2), gammaisation is a serious candidate to restore agreement between phenomenological predictions and experiment in E.A.S. about the absorption of showers. For exemple maximum's depth T_{max} as a function of the primary energy E is shown fig 1 for pure proton, pure iron primaries and mixed composition (60% p + 40% fe)
Dotted lines and full lines are respectively without and with gammaisation.
It can be noticed that the relatively large proportion of iron in the mixed composition

is a consequence of the small saturation value ($\langle a \rangle = 3.$) of the ratio $\langle n_\gamma \rangle / \langle n_s \rangle$

The comparison of the Tien-Shan dependence $N_\mu(N_e)$ with SBM calculation results shows some serious discrepancies (fig. 2) On this figure are drawn for fixed sizes N_e and mean zenith angle $\theta = 22°$,the muon sizes N_μ for pure proton and iron primaries.

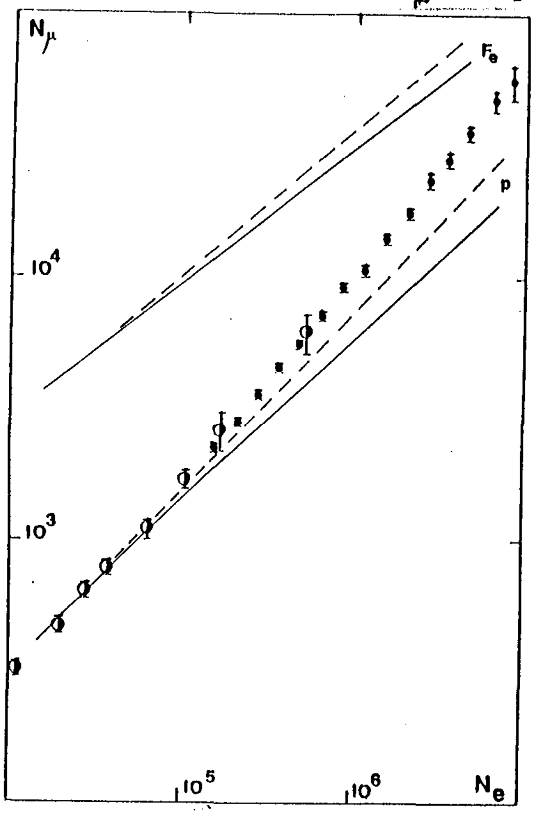


fig. 2

Dotted lines and full lines are respectively dependences without ($\langle a \rangle = 1.$) and with gammaisation.

As shown in ref. (1) the muon size dependence $N_\mu \sim N_e^\alpha$ simulated by the SBM model without gammaisation is defined in the size interval 10^5-10^7 by the parameter $\alpha = 0.67$

This value is different from the experimental one :

$\alpha_{exp} = 0.800 \pm 0.008$ (6)

If we take into account the gammaisation this situation is worse for the largest values of N_e.

Indeed,the production of additional γ increases with energy,so imposes a flatter dependence of $N_\mu(N_e)$ i.e. $\alpha = 0.61$

It is possible to obtain results in better accordance with experimtal ones with a mixed primary composition.However the N_μ-N_e variation is never steep enough in comparison with the correspodant experimental results.

If we do not take into account the process of gammaisation (dotted lines fig.3),in the size interval 10^4-10^6 and in the range of distance 5-100 m,a good agreement is obtained for the lateral distributions of muons (the origin of the experimental points is given in ref. (1))

However,for large sizes and far from the axis of showers (R > 100m),simulated densities become slightly smaller than the experimental ones. This gives,because the large number of muons far from the axis,the underestimation of $N_\mu(N_e)$ (see fig. 2)

As expected from results shown in fig. 2,with production of additional γ,the situation is the same for small showers and becomes less favorable for large sizes ($N_e \sim 10^6$) (full lines on fig. 3)

4. Discussion A consequence of the gammaisation hypothesis for high energies (E > 10^5 GeV.) is the decrease of the ratio N_μ/N_e for showers initiated by primaries with fixed energy. This imply for showers registered with fixed sizes a smoother variation of $N_\mu(N_e)$ than is obtained with the standard SBM model.

mixed primary composition.

However, because the agreement of the protonic showers for smallest sizes ($N_e \sim 10^4$) and the important decrease of the primary energy spectra, the effect of heavy primaries remains not large enough.

In any case, the N_μ-N_e dependence is never steep enough in comparison with the correspondant experimental results.

The agreement with experiment can be obtained with help of a stronger increase of multiplicity $\langle n_s \rangle$ with energy. This result is confirmed by the results of other authors (7) with calculations carried out under the assumption of SBM where $\langle n_s \rangle \alpha E^{0.25}$ Ours, coming from accelerators data is equivalent to $\langle n_s \rangle \alpha E^{0.13}$

However we have to notice that no experimental arguments from the accelerator region allow one to adopt such a strong dependence of secondary multiplicity on the energy of interactions.

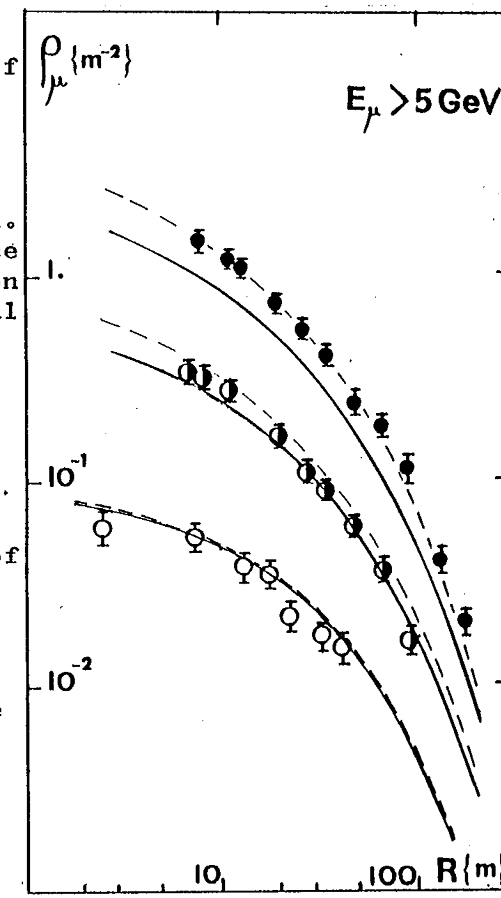


fig. 3

5. Conclusions

We have analysed E.A.S. electron and muon components in the Tien-Shan experiment on the basis of the SBM model including the "gammaisation" hypothesis. We have shown that with a correct description of the longitudinal development, a good agreement between experimental and calculated results is ontained if we use a mixed primary composition rich in proton and a stronger variation of multiplicity of secondaries with energy than the one given by accelerators results.

References :

(1) J. Procureur, J.N. Stamenov et al. to be published in J. Phys. G
(2) S.I. Nikolski (1970) Trudi FIAN 46, 100
(3) J.N. Capdevielle, J. Procureur J. Phys. G 10 (1984), 705
(4) N. Yamdagni (1982) proc. Workshop on Very High Energy Cosmic Ray Interaction, University of Pennsylvania, p 36
(5) S.I. Nikolski and J.N. Stamenov, Proc. 18th ICCR (1983) OG4-14
(6) I.N. Kirov, S.I. Nikolski et al., Proc. 7th ESCR (1980), 360
(7) A.D. Erlykin et al. Moscow (1984) FIAN n° 14