# SENSITIVITY OF DEPTH OF MAXIMUM AND ABSORPTION DEPTH OF EAS TO HADRON PRODUCTION MECHANISM

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Comparison of experimental data on depth of EAS development maximum in the atmosphere, $t_m$, and path of absorption, $\lambda$, in the lower atmosphere of EAS with fixed particle number in the energy region $E_0=1015-10^{18}$eV with the results of calculation show that these parameters are sensitive mainly to the inelastic interaction cross section and scaling violation in the fragmentation and pionization region. The data are explained in a unified manner within the framework of a model in which scaling is violated slightly in the fragmentation region and strongly in the pionization region at primary cosmic rays composition close to the "normal" one and a permanent increase of inelastic interaction cross section. It is shown that, while interpreting the experimental data, disregard of two methodical points causes a systematic shift in $t_m$: i) shower selection system; ii) EAS electron lateral distribution when performing the calculations on basis of which the transfer is made from the Cerenkov pulse FWHM to the depth of shower maximum, $t_m$.

Two models (I,II)[1] were used as basic ones in our simulation. In the both models, an increase in cross section of hadron-air nuclei interaction was taken in the form $\sigma_h^{in}(E_0)=\sigma_h^{in}(E')(1+\alpha_h \ln(E_0/E'))$ where E'=100 GeV, $\alpha_h$ =0.04. In model I, at $E_0=10^{14}-10^{15}$eV scaling is violated in both pionization and fragmentation regions, model II being quasiscaling.

For a set of fixed values of $E_0$ the double distributions over particle number at sea level and $t_m$ were obtained. Using the Baiece theorem the distribution over $E_0$ at fixed particle number was derived regarding the power-law primary energy spectrum ($I(>E_0)\sim E_0^{-\gamma}$).

Table 1 lists the results of calculations for a 1030 g/cm$^2$ obseravtion depth. For each version 100 showers were simulated. The values of the threshold energy Ethr of tracing a nuclear cascade are listed in Table 1. Mixed composition of primary radiation was regarded (see Table 2).

An examination of Table 1 shows that at a fixed particle number at sea level, N, the value $t_m^{meas}$ is sistematically overestimated regardless of a measurement method. The overestimate depends on $E_0$ and the interval width $\Delta$ N. $E_0$ increasing up to $\sim 10^{18}-10^{19}$eV, the overestimation decreases to zero.

Fig.1 illustrates the difference of distributions over $t_m$ in the case of a fixed primary energy and in the case

Table 1

| $E_0$, eV | $E_{thr}$, GeV | Model I | | | Model II | | |
|---|---|---|---|---|---|---|---|
| | | $\bar{t}_m$, g/cm$^2$ | $\bar{t}_m^{meas}-\bar{t}_m$, g/cm$^2$ | | $\bar{t}_m$, g/cm$^2$ | $\bar{t}^{meas}-\bar{t}$, g/cm$^2$ | |
| | | | $\gamma=1.7$ | $\gamma=2.2$ | | $\gamma=1.7$ | $\gamma=2.2$ |
| $10^{14}$ | 5 | 427±7 | +220 | +240 | 467±9 | +235 | +251 |
| $10^{15}$ | 5 | 490±7 | +206 | +226 | 541±8 | +184 | +210 |
| $10^{15}$ | 10 | 485±7 | +161 | +181 | --- | --- | --- |
| $3\cdot10^{15}$ | 5 | 520±7 | --- | --- | --- | --- | --- |
| $10^{16}$ | 5 | --- | --- | --- | 618±8 | +158 | +170 |
| $10^{17}$ | 50 | --- | --- | --- | 667±15 | +57 | +67 |

of a fixed particle number at observation level.

Table 2

| A | 1 | 4 | 14 | 26 | 50-56 |
|---|---|---|---|---|---|
| % | 41 | 9 | 15 | 17 | 18 |

Table 3 compares results of Cerenkov light FWHM calculations regarding($\tau_2$) and disregarding($\tau_1$) shower lateral distribution. The latter approximation assumes all photons to be delayed as if they were emitted from the shower core. Further we present the values of differences between $t_m$ evaluated using $\tau_1$ and $\tau_2$ : one can see that the use of $t_m(\tau_1)$ dependence instead of $t_m(\tau_2)$ leads to an overestimation of $t_m$.

Table 3

| $E_0$, eV | R, m | $\tau_1$, ns | $\tau_2$, ns | $\Delta t_m = t_m(\tau_2) - t_m(\tau_1)$, g/cm$^2$ |
|---|---|---|---|---|
| $10^{15}$ | 200 | 8.5 | 4.1 | 110 |
| $10^{15}$ | 300 | 25.2 | 16.9 | 90 |
| $10^{15}$ | 400 | 40.6 | 33.9 | 50 |
| $10^{17}$ | 200 | 19.5 | 13.2 | 150 |
| $10^{17}$ | 400 | 54.3 | 63.4 | 50 |

Fig.2 compares the summary of experimental data on $t_m$ with the results of our calculation. At chemical composition close to the normal one the experimental data are well described by model I.

Fig.3 presents the comparison of the experimental data from /3/ on absorption path of EAS with fixed particle number N near sea level with our calculation. Calculation in terms of model I at $\alpha_h \approx 0.04$ and "normal" composition is consistent with the experiment.

## References

1. Antonov R.A., Ivanenko I.P., Kuzmin V.A., Roganova T.M., Yadernaya Fizika, 1984, v.40, vyp. 5(11), 1222.
2. Ivanenko I.P., Kanevsky B.L., Roganova T.M., Pis'ma v JETP, 1978, 28, 704; Yadernaya Fizika, 1979, 29, 694; Preprint FIAN N 001, Moscow, 1979.
3. Nagano M. et al., J. Phys. G.: Nucl. Phys., 1984, 10, L235.

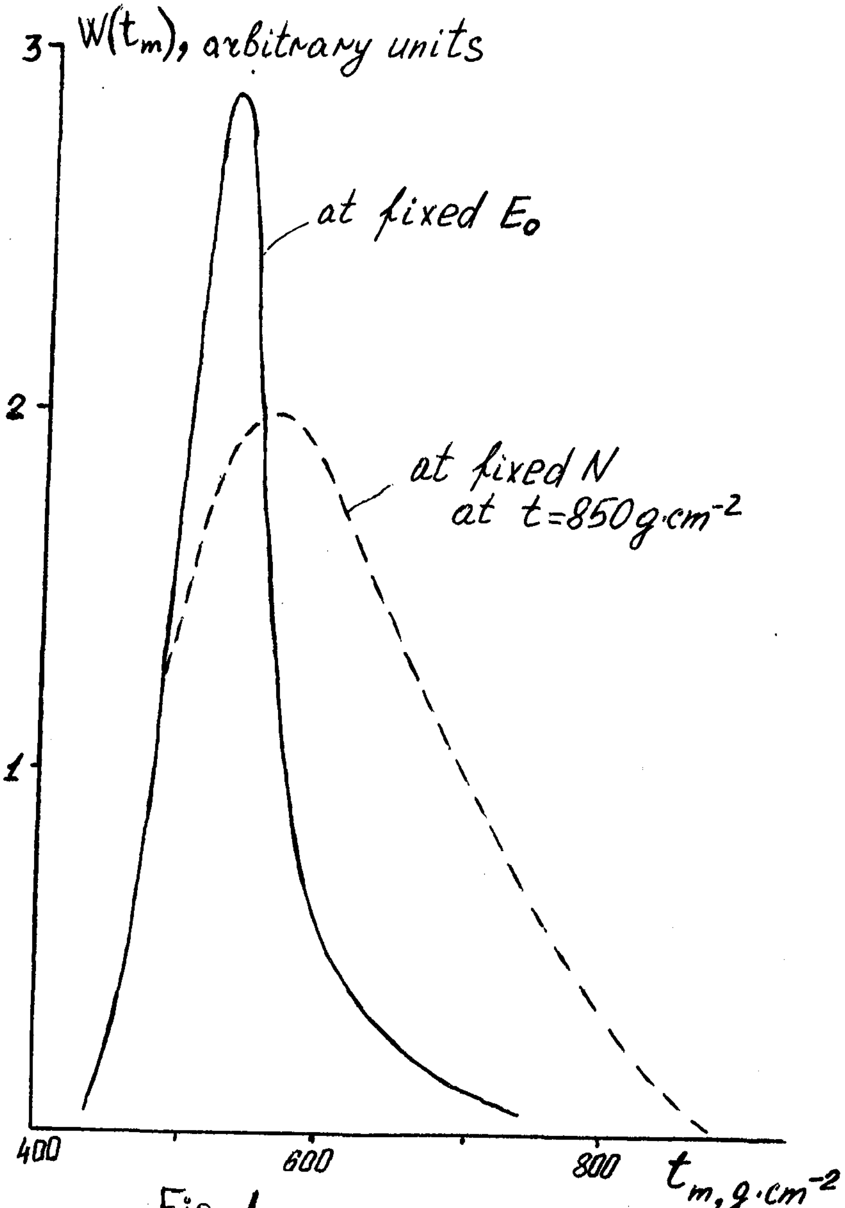
3
2
1
W(t_m), arbitrary units
at fixed E₀
at fixed N
at t=850g·cm⁻²
400
600
800
t_m, g·cm⁻²

Fig. 1

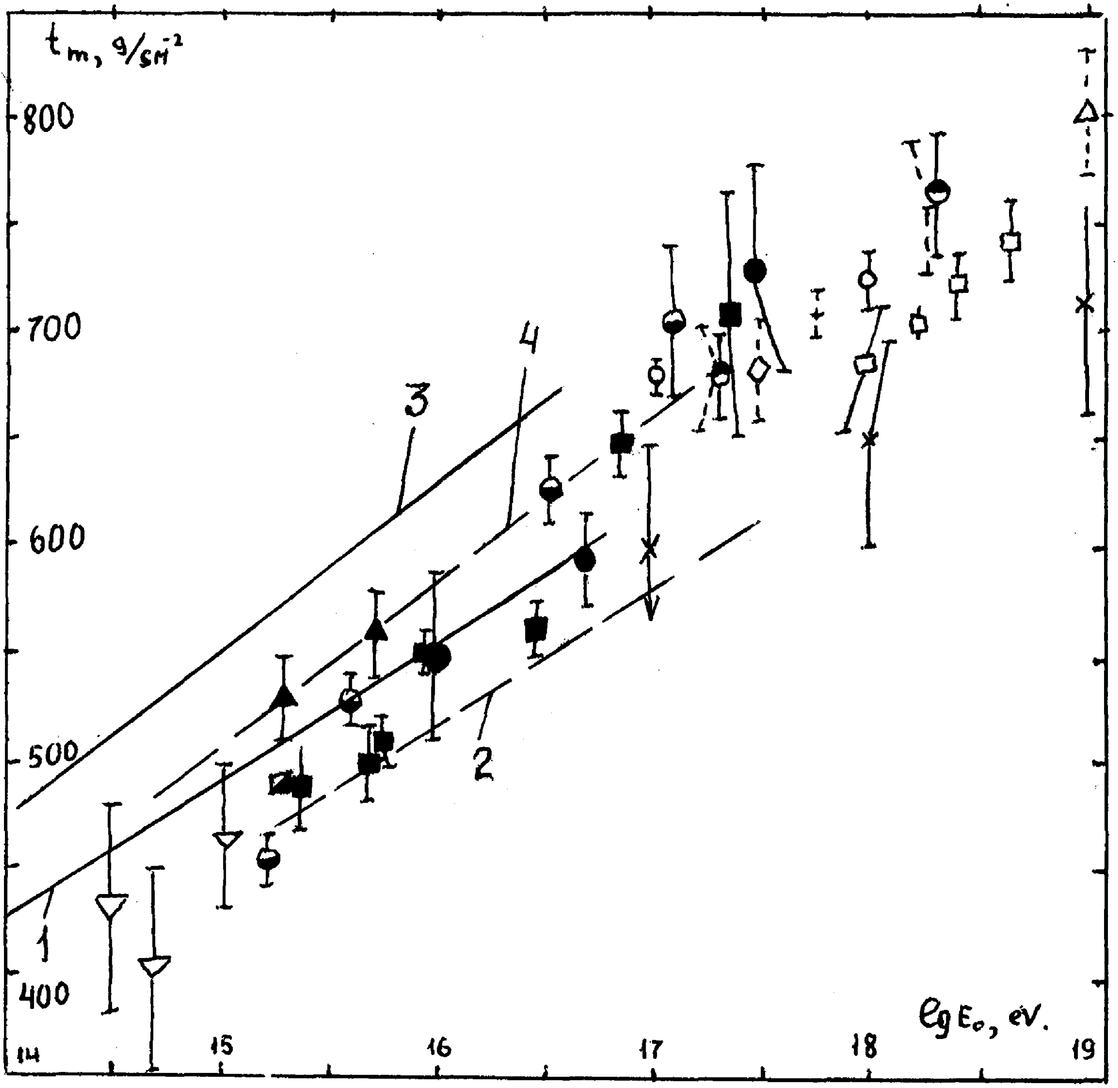
$t_m$, g/sm$^{-2}$
800
700
600
500
400
14
15
16
17
18
19
lg $E_0$, eV.
1
2
3
4

Fig. 2.

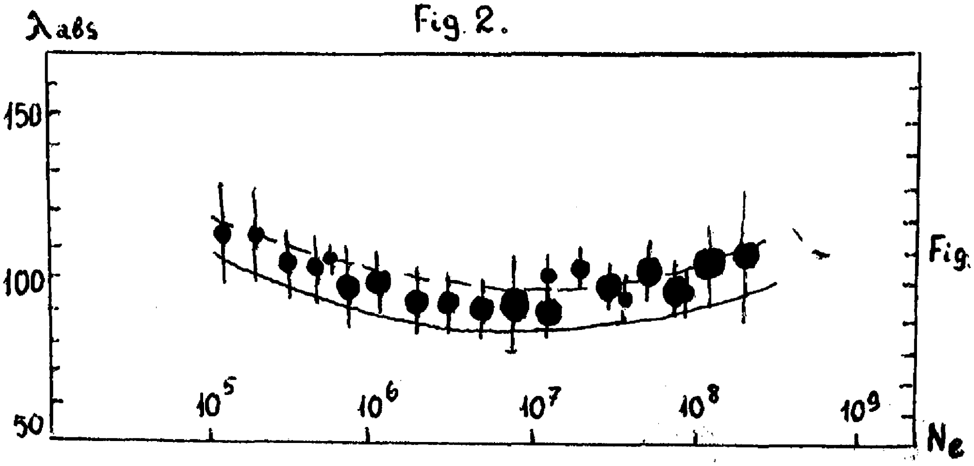
$\lambda_{abs}$
150
100
50
$10^5$
$10^6$
$10^7$
$10^8$
$10^9$
$N_e$

Fig. 3