PRIMARY CHEMICAL COMPOSITION FROM SIMULTANEOUS RECORDING OF MUONS INDUCED CASCADES AND ACCOMPANYING MUON GROUP UNDERGROUND

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ABSTRACT

A new method to estimate the mean atomic number of primary cosmic rays in energy range 10^3-10^5 Gev/nucleon is suggested. The Baksan underground scintillation telescope data are used for this analysis. The results of 7500 h run of this experiment are presented.

Introduction. The big area and calorimetric properties of Baksan underground scintillation telescope (1-3) allows a simultaneous measurement of cascade energy and the multiplicity of accompanying muons. Assuming superposition model one can calculate the energy E_0 of primary nucleon, responsible for a given cascade, more strictly-distribution of these energies. Suppose we know the muon multiplicity at the given depth as a function of primary nucleon energy, namely $N_0=f(E_0)$. The experimental value is expected as $N=f(E_0)\cdot\bar{A}$, where $\bar{A}$ is the mean primary atomic number. Comparing experimental data (N) with the theory ($f(E_0)$) we obtain $\bar{A}=N/f(E_0)$.

The energy distribution of primary nucleons, responsible for cascade energy E_c. This was calculated in several steps:

1. The muon energy spectrum at our depth was taken in a form

$P(E_{\mu 0})dE_{\mu 0}=(220+E_{\mu 0})^{-3.7}dE_{\mu 0}$, $E_{\mu 0}$ in Gev.

2. The muon energy distribution, responsible for E_c:

$P_1(E_{\mu 0},E_c)dE_{\mu 0}=P(E_{\mu 0})\cdot W_\mu(E_{\mu 0},E_c)dE_{\mu 0}$, where $W_\mu(E_{\mu 0},E_c)$-probability of energy transfer E_c by muon with energy $E_{\mu 0}$ taking into account bremstrahlung, "knock-on" electrons, photonuclear and the e^+e^- production (4-7).

3. Taking into account muon energy losses to our depth x obtain muon production spectrum:

$$P_2(E_\mu,E_c)dE_\mu=0.7\cdot P_1(0.7\cdot(E_\mu-220),E_c)dE_\mu,\ 0.7=\exp(-b\cdot x).$$

4. Transform from muon to pion spectrum:

$$P_3(E_\pi,E_c)dE_\pi=dE_\pi\int_{nE_\pi}^{E_\pi}\left(\frac{\gamma+1}{1-n^{\gamma+1}}+\frac{\gamma+2}{1-n^{\gamma+2}}\cdot\frac{E_\mu}{B(\theta)}\right)\frac{E_\mu^{\gamma+1}\cdot P_2(E_\mu,E_c)dE_\mu}{E_\pi^{\gamma+2}\cdot(1+E_\pi/B(\theta))},$$

$n=(m_\mu/m_\pi)^2$, $B(\theta)=110/\cos\theta$, θ-zenith angle, $\gamma=1.7$-integral exponent of primary spectrum.

5. The nucleons energy distribution:

$$P_4(E_0,E_c)dE_0=\frac{dE_0}{E_0^{\gamma+2}}\cdot\int P_3(E_\pi,E_c)\cdot W_\pi(E_0,E_\pi)dE_\pi,$$ where $W_\pi(E_0,E_\pi)$- is the inclusive production function taken from (8).

Fig.1 shows the results of this calculations for several cascade energies E_c. The mean values of the variables involved are also shown in the table in Tev.

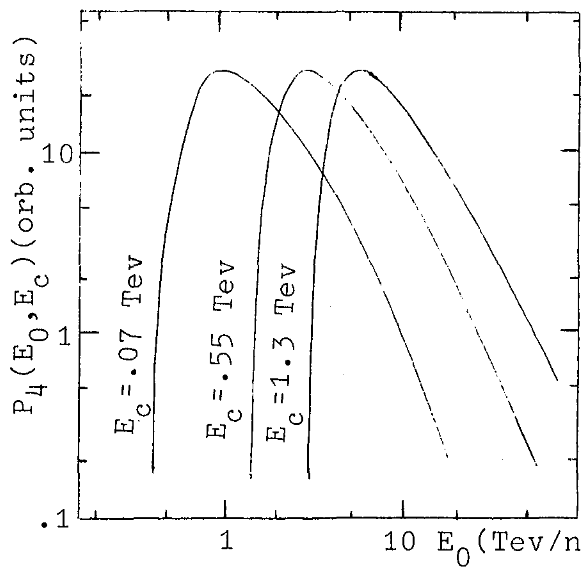

Fig.1

The multiplicity of accompanying muons. Two corrections should be made to experimentally observed number of accompanying muons m, which is only a fraction of the total number N. The correction factors $\bar{\Delta}$ and $\bar{k}$ have following meanings: $\bar{\Delta}$-mean ratio of muons inside telescope area to the total number N ($\bar{\Delta}<1$ due to the finite size of telescope): $\bar{k}$-mean ratio of muons, lost in the cascade core, to the total number N. Both correction factors depend on the cascade energy E_c and muon distribution function. The latter was taken in the form:

$$F(r,E_\mu,\theta)=E_\mu^{-0.7}\cdot\exp(-(r/r_\mu)^{0.7});\ r_\mu=\frac{220\cdot r_0}{E_\mu\cdot\cos\theta}, r_0=6.2\text{ m},$$

cosθ=0.82,which gives a good fit to the decoherence curve and stopping muon data.As one can see from the table calculations show an increase of $\bar{\Delta}$ as the E_c increases due to "attraction" of cores of muon group.

Table

E_c	from	.05	.10	.21	.44	.74	1.18	1.47	2.94	6.62
	to	.10	.21	.44	.74	1.18	1.47	2.94	6.62	-
$\bar{E}_c$	(Tev)	.07	.14	.29	.55	.90	1.30	1.91	3.38	8.21
$\bar{E}_{\mu 0}$		.43	.54	.79	1.25	1.89	2.60	3.73	7.26	14.9
$\bar{E}_\mu$		.84	1.0	1.36	2.0	2.94	3.97	5.60	10.7	21.7
$\bar{E}_\pi$		1.17	1.27	1.75	2.56	3.72	5.04	7.17	14.0	28.8
$\bar{E}_0$		4.19	5.44	7.90	12.6	18.9	25.8	36.6	67.7	126
$\bar{m}$		.58	.89	1.17	1.81	2.25	2.63	3.38	6.20	9.67
$\bar{\Delta}$		.21	.23	.25	.28	.30	.31	.32	.32	.33
$\bar{k}$		.03	.04	.07	.08	.09	.10	.11	.13	.16
$\bar{N}$		3.3	4.8	6.3	9.1	10.9	12.6	16.4	32.8	57.9

The correction was made as $\bar{N}=\bar{m}/(\bar{\Delta}-\bar{k})$.Note that muon, responsible for cascade,is not included in this formula also in experimental values in the table.

Conclusions.The comparison of obtained multiplicities N as a function of E_0 with the expected $f(E_0)$ (10-11) is shown in the fig.2.

Curves 1;2;3correspond to $\bar{A}$=1;3.5;4.5.By definition mean atomic number in our case is

$$\bar{A}=\sum \beta_i \cdot A_i^2 / \sum \beta_i \cdot A_i ,$$

$\bar{A}$=3.5 correponds to the composition: β_1=.939, β_4=.055, β_9=.0009, β_{14}=.0035, β_{28}=.0011, β_{56}=.0036,which fits well both direct experimental data at 1 Gev/nucleon and Baksan gene-

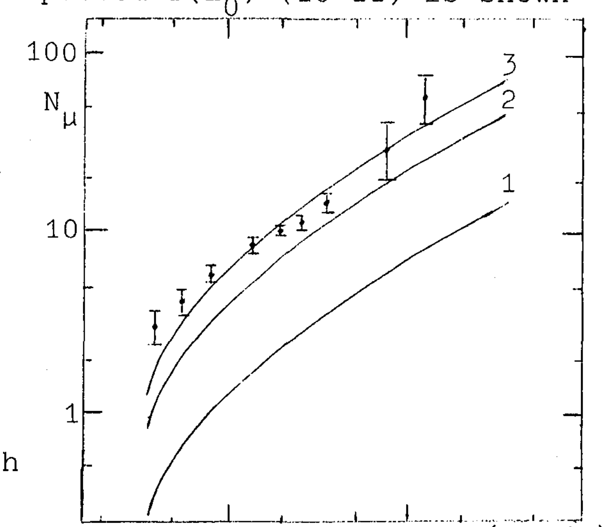

Fig.2

ral multiplicity spectrum.The data of this experiment is better fit by $\bar{A}$=4.5,but the difference is not significant on the basis of a possible systematic error.The conclusion is that in the range 1-10^5 Gev/nucleon there is no visible change of the mean atomic number.

References

1. A.E.Chudakov et al. Proc. of 16 ICRC,v.10,p.188,1979.
2. A.E.Chudakov et al. Proc. of 16 ICRC,v.10,p.175,1979.
3. Yu.M.Andreyev et al. Proc of 17 ICRC,v.7,p.67,1981.
4. E.V.Bugaev et al. The cosmic ray muons and neutrino,Moscow, Nauka,p.15,1970.
5. S.Hayakava The cosmic ray physics,Moscow,Mir,v.2,p.511, 1970.
6. E.V.Bugaev et al. Cosmic ray muons and neutrino,Moscow, Nauka,p.23,1970.
7. L.B.Bezrukov and E.V.Bugaev Proc of 17 ICRC ,v.7,x.90,1981.
8. A.M.Hillas Proc. of 16 ICRC,v.6,p.13,1979.
9. E.V.Budko et al. Proc of 19 ICRC,HE.5.1-12
10. I.W.Elbert and P.Summers Preprint UUHEP,83/20,University of Utah.
11. A.D.Erlykin Private communication.