Cosmic Ray Composition between 10^{15} to 10^{17} eV obtained by Air Shower Experiments

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abstract

Based on the air shower data, the chemical composition of the primary cosmic rays in the energy range 10^{15}-10^{17}eV has been obtained. The method is nased on a well known N_e-N_μ and N_e-N_γ. Our simulation is calibrated by the CERN SPS $p\bar{p}$ collider results and very reliable.

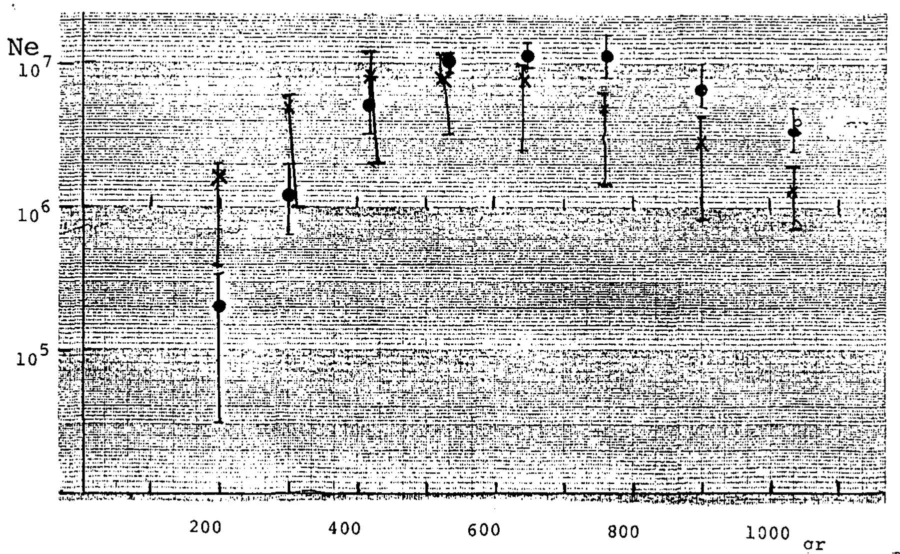
1. Introduction and Model

When the first $p\bar{p}$ collider results from CERN has reported in the end of 1981, we have started a Monte Carlo calculation with the use of the data on the nuclear nuclear interaction. The first result has been already published in a proceeding of the Bagalore conference and the simulation model is described in detail therin[1)], however, here we describe briefly the simulation model : $\langle n_s \rangle \propto E_o^{1/6}$, $\sigma_{tot} \propto (\ln\sqrt{s})^2$, $K/\pi \sim 0.15$, $\langle P_T \rangle \sim 0.4$ GeV/c and no energy dependency. The effect of geo-magnetic field and the scattering in the air have been taken account of.

2. Transition Curve

The transition curve of the electron number N_e is shown in Fig. 1 as a function of the altitude. ● and X represent the proton and iron primaries respectively with the same incident energy $E_o = 2 \times 10^{16}$eV. The error bar implies the region of 90% air shower involved, while ● and X represent the mean value.

Fig. 1 Transition curve for proton(o) and iron(X)



3. N_e-N_μ plot and Trigger Bias

It is interesting to compare present result with the previous calculation by Jōgo [2]. Our result of proton(----) primary fits well with the result based on CKP model for proton promaries rather than sacling model with iron primaries calculated by Jōgo. However we must take account of the trigger bias involved in the data taking. As shown in Fig. 3, even if the composition of primary cosmic rays could be 90% iron(x) nad 10% proton(●) beyond 10^{15}eV, it is identified as proton dominant by the N_e trigger. To avoid such a misunderstanding, N_μ trigger is preffered.

Fig. 2 N_e-N_μ plot

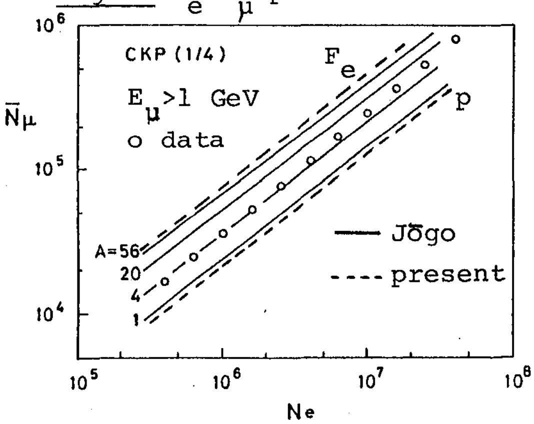
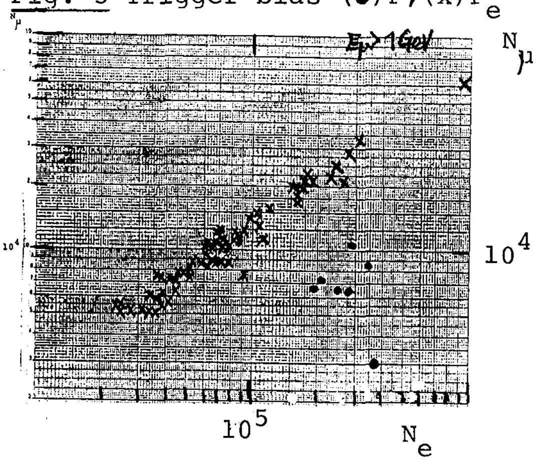


Fig. 3 Trigger bias (●)P,(x)Fe



4. N_μ-N_e Trigger Data

Fig. 4 represents N_e-N_μ contour plot by N_e trigger. In a range of $N_e \gtrsim 10^7$, no trigger bias is observed even if the data have been taken by N_e trigger[3].

In the same N_e-N_μ plot of Fig.4, we draw the line with the same incident energy for various kind of primaries (Fig. 5). The highest peak of the contour corresponds to the size s=1.1. The corresponding size for each primary is s=1.0-1.2 for proton, s=1.2-1.3 for He, s=1.3-1.4 for CNO, and s=1.4-1.5 for iron in 900 grams(Akeno).

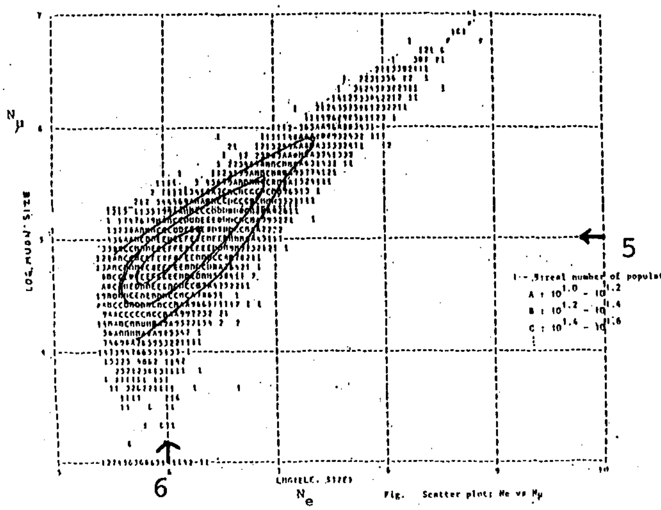


Fig. 4 N_μ-N_e plot

a,b,c corresponds the number of events :

a : $10^{1.0}$-$10^{1.2}$

b : $10^{1.2}$-$10^{1.4}$

c : $10^{1.4}$-$10^{1.6}$

(data from Ref. 2)

real number means real population

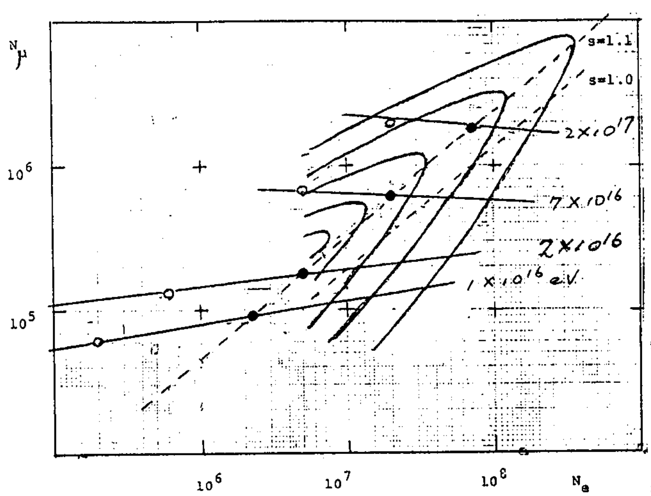


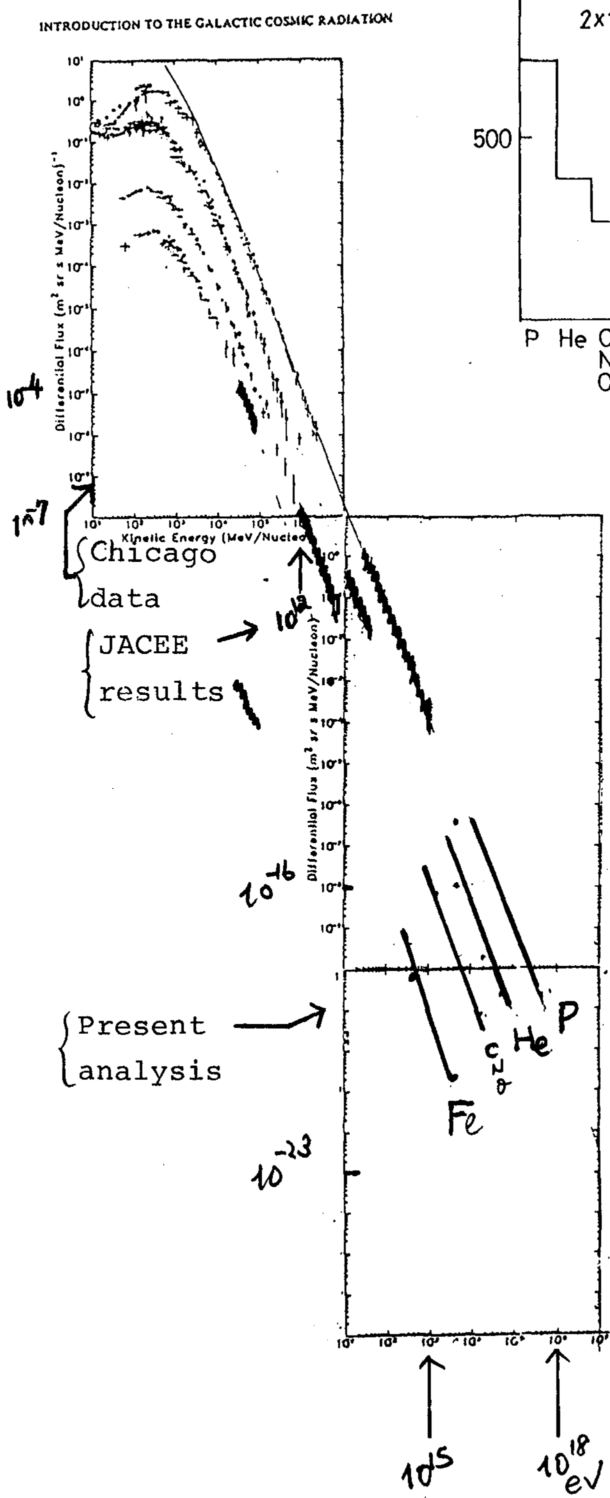
Fig. 5 Contour plot

the same incident energy line is drawn by line. the same age is represented by the dotted lines.

(data from Ref. 3)

Note added: above logic holds even if the primary composition is 90% F_e+ 10 % P. We assumed peak corresponds to proton.

Fig. 7



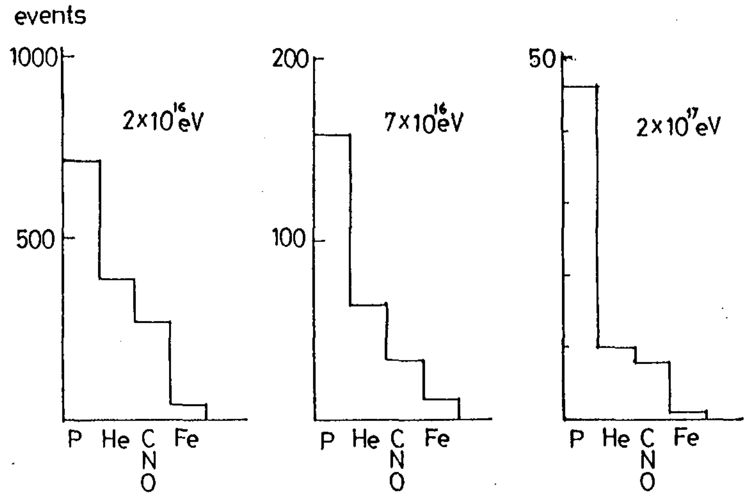


Fig. 6 Primary composition

The number of events which has the same energy(E_o) and the same size has been counted from Fig. 4 and 5. The distribution is given in Fig. 6.

5.Conclusion

It is interesting to plot present result on the differntial spectrum obtained lower energy experiments(Fig. 7). From Figs. 6 and 7, we conclude the composition of primaries in the range of energy 2 X10^{16}eV and 2 X10^{17} eV, the iron component does not become dominant.

References

1) Y. Muraki,A.Okada; 18thICRC at Bangalore, 7 (1983), 54.

2) N. Jogo; PHD thesis to Tokyo Univ. (in English) (1981)

3) Akeno group; 18thICRC,11(83)281.