$0.1 < K_c < 0.3$, than was computed. The difference may be due to diagram of Fig. 1a, which is not taken into account.

Actually, according to ref.[4] the N-N interaction cross-section due to processes of Fig. 1a-type can give about 30% of the total one, and their inelasticity coefficients are within the interval $K_c < 0.3$.

5. From the above comparison it is seen that one-meson approximation with both the diagram of the Fig. 1a and that of Fig. 1b can explain main characteristic properties of N-N interaction at $E_L = 300$ GeV. The cases with relatively large values of inelasticity coefficient ($0.4 < K_c < 0.8$) find an explanation, as well as existence of symmetric and asymmetric showers. Thus, it is possible that multimeson processes (so-called head-on collisions) do not contribute very essentially to the N-N interaction at high energies.

It should be stressed that the present consideration cannot be of high accuracy, but it is an estimating character. Partly this is due to the absence of experimental data on π-N interactions for $\omega_L = 10 \sim 20$ GeV.

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III-7-15. Review of High Energy Theories

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The high energy theory is related to the theories in various fields and covers the vast domain of phenomena. It is not possible, therefore, to make an over-all review of high energy theory. Here we shall confine ourselves to the theory of elementary interaction, namely to the multiple particle creation in nucleon-nucleon or in pion-nucleon collision.

The experiments on jets, on which many excellent works have been reported at this conference, seem to indicate that there exist various types of collision. The so-called "double maxima stars" may be considered as one of them. They have been analyzed by the use of, for instance, "fire-ball" model. Although someone may be reluctant to recognize this phenomenon as revealing a special kind of collision, this phenomenon should not be treated as a simple fluctuation.

Another distinct type of collision can be seen, for example, in the unusual jet observed in a big emulsion chamber placed on Mt. Norikura[1]. This jet contains a very high energy π^0-meson besides rather low energy π^0-mesons in one family.

Now, we shall try to show how to describe these various collisions. The collision process can be represented schematically in a diagram (Fig. 1). Between the interacting

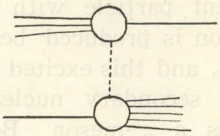

Fig. 1.

nucleons the momentum and energy are exchanged to each other. If this exchange process can be approximated by single boson exchange, this collision may be classified as peripheral. Moreover, if the exchanged boson can be fairly represented by a pion, then we can use the characteristics of pion-nucleon collision to analyze the nucleon-nucleon collision. Although this treatment may be considered to be phenomenological, this reduces the character of nucleon-nucleon collision to that of pion-nucleon collision. Dremin and Chernavsky[2] were the first to obtain the expression for the cross-section of nucleon-nucleon collision using this method. Salzman and Salzman[3] extensively investigated this method and applied it to several cases. Two papers by Chernavsky and others, submitted to this conference, also treated this method. In this treatment, the energy-momentum four-vector representing the exchanged boson is space-like. Thus we need the off-the-mass-shell collsion cross-section even if the one-boson-exchange approximation can actually represent an aspect of the character of nucleon-nucleon collision. Usually, the off-the-mass-shell pion-nucleon cross-section is replaced by the physical cross-section. This replacement has not been proved valid, although it may be practically a good approximation. Further assumption should be made on the asymptotic behaviour of pion-nucleon cross-section, in order to make the asymptotic behaviour of nucleon-nucleon cross-section a physically plausible one. These assumptions and approximations should be further investigated from the field theoretic piont of view. Nevertheless, under some approximations this method seems to give a useful tool to analyze the experiments in rather low energy region, say about 10^{11} eV or so. In fact, Chernavsky and others showed that the result of one-pion-exchange approximation is in fairly good accord with the experimental data of 300 GeV. Moreover, the double maxima phenomena may be explained by suitably taking the angular distribution of secondary particles in pion-nucleon collision.

In connection with the one-boson-exchange model, one point should be noticed. If one also wants to treat pion-nucleon collision in a similar method, the simple one-boson-exchange model should be modified and the knowledge on the pion-pion collision cross-section should be used. Thus if one wants to consistently go further, this modification leads to another class of diagrams (Fig. 2). This diagram may be useful when we want to take into consideration the pion-nucleon, kaon-nucleon interactions and other similar effects. Diagrams of this nature were also considered by Zatsepin[4] at this conference.

Next we proceed to the fire-ball model. The term "fire-ball" has been used in different meaning. Here, "fire-ball model" is used in the meaning not only that the created particles can be divided into two groups but also that in the centre of mass system of each group the angular distribution of the secondary particles belonging to the group is isotropic. This feature would be explained as the result of interaction among created particles, pion-pion interaction as an example. Due to this interaction, the "hot spot" which is produced at the instance of collision will be "cooled" down. This

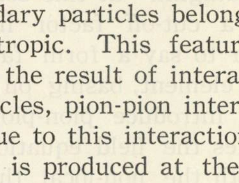

Fig. 2.

cooling process and the subsequent expansion process of pion gas have been described in terms of hydrodynamical model which originates from Landau's work. Many attempts to modify the Landau theory and many critical arguments as to its validity have been made. Emelyanov and Rosental[5] introduced the effect of viscosity into hydrodynamical treatment and showed that the dependence of the multiplicity of created particles on the incident energy can change from its original Fermi-Landau value, $E_0^{1/4}$, towards the Heisenberg value $E_0^{1/2}$. The introduction of viscosity tends to make the energy equipartitioned especially in the top region of pion-gas flow, which fact is favourable to the formation of fire-ball.

More critical argument against Fermi-Landau theory was made by Milekhin[6] who showed that the equation of state of pion gas might be different from that of ideal fluid.

Namiki *et al.*[7] proposed a method to evaluate the momentum spectrum of this "cooled" pion gas by applying the theory of condensation of Bose-Einstein gas. Their result shows that the momentum spectrum of pion has a peak near μc, μ being the rest mass of pion. This result agrees qualitatively with the character of fire-ball and with the well established fact that transverse momenta of secondary particles are of the order of μc.

Another interesting explanation of the constancy of transverse momenta was proposed by Wataghin[8] at this conference. He introduced a cut-off factor in momentum space, better to say a form factor in collision matrix element, basing on his non-local theory. To introduce pion-pion interaction usually makes the field equation non-linear. We have both the non-local theory and the non-linear theory. At present time, we can not answer which theory is more suitable to explain the existing phenomena.

As to the mechanism of creation of "hot spot", a simplified model was proposed by Daiyasu and others[9]. But this model seems to be an over-simplification, and the validity and usefulness of this model are still open to question.

Next, we would like to focus our attention to the unusual jet observed by Norikura emulsion group, which was mentioned before. In this jet a π^0-meson emerges with very high energy, the energy being about 10^{14} eV, in contrast to the other π^0-mesons which have rather low energies. Thus, the energy spectrum of produced π^0-mesons has, in this case, a shape quite different from the usual one. This feature seems to indicate a new characteristics of extremely high energy event. According to the interpretation of Norikura group, this event may be understood as follows. By the nuclear interaction of the incident particle with air nuclei an excited baryon is produced besides the low energy pions, and this excited baryon decays or makes a secondary nuclear interaction and produces a π^0-meson. Because of its short life-time, this excited baryon may not be a known hyperon. Rather, it may be a highly excited state of nucleon, whose nature should be further investigated in detail.

Professor Peters[10] drew our attention to the role of hyperon in cosmic ray phenomena. Indeed, hyperons play an important role in cosmic ray phenomena and the presence of hyperons in cosmic ray particles affects the shape of spectrum of various quantities, such as the size spectrum of EAS and the energy spectrum of γ-rays and the charge excess of cosmic ray particles. However, to take into account the effects of only known hyperons is not enough to explain quantitatively the observed data, for instance the steepness of γ-ray energy spectrum or the presence of very high energy π^0-meson mentioned before.

Thus we see that, on the one hand, hyperons and other strange particles play an important role in the cosmic ray phenomena while, on the other hand, the cosmic ray phenomena seem to reveal the yet unknown character of very high energy nuclear interaction, further investigation of which will lead to more profound understanding of elementary particles.

Another tempting interpretation of the unusual jet was proposed by Hasegawa[11]. He assumed the existence of new quantum in the multiple particle creation process. According to his idea, pions are created in many groups and each group has a characteristic mass, the magnitude of which is about twice nucleon mass. Each group may be considered to act as a quantum in the production stage of particles. He analyzed the data from this point of view.

Although the statistics is not rich and his assumption may be invalid, it would be certain that some new approaches like this would be necessary to understand the extremely high energy event. If we can observe a fairly large number of events of such nature, they will provide us valuable information on the character of elementary interaction and perhaps on the structure of elementary particles.

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Discussion

Yamaguchi, Y.: According to accelerator data, the total cross section for π-N and N-N collisions become essentially constant above, say, a few GeV (kinetic energy). We have heard in this conference, the interaction cross section of nuclear active particle colliding on a nucleon might be somewhat larger than the values known from accelerator data. In this connection, I would like to draw your attention to familiar theoretical arguments centered around the Pomeranchuk theorem, and I hope that in near future this possible discrepancy would be cleared out. It is now conjectured that the total cross-section for collision of two strongly interacting particle would become spin— and isospin— independent at high energy regions, and antiparticle-particle total cross-section approaches to particle-particle total cross section there. Here I would like to make a rather ambitious statement.

If there *could occur* some substantial change in the total cross-sections at higher energies than available accelerators can provide now, it would be extremely tempting to assert that all total cross section for strongly interacting particle collision might be equal and independent of any quantum numbers specifying the initial particles (baryon number, spin, isospin, strangeness, etc.). I notice that π-N and K-N cross-section are not very different according to CERN data.

Peters, B.: The evidence for an increase of nuclear cross-section above$\sim 10^{14}$ eV is, I believe, all dependent on evidence that at high energy the primary energy is converted into π-mesons more quickly than at lower energy. This can be, it seems, explained also if one attributes a larger role to complex nuclei. This means that several parallel nuclear cascades move together through the atmosphere and this leads to a large rate of conversion of primary energy into pion energy.

Nishimura, J.: As far as we know, in the discussion on the EAS, Tokyo air-shower group, M.I.T. people and others agree that the interaction mean free path is (100 ± 10) g/cm^2. This value is consistent with the view that the N-N cross section is 40 mb. So the cross section remains constant up to 10^{15} eV$\sim 10^{17}$ ev.

Yamaguchi: The cross section I am interested in is for the elementary collision. Whereas the interaction mean free path derived from the extensive air-shower might not be free from some ambiguities, because it requires some manipulations based on a specific model.

Oda, M.: I wish to correct Dr. Yamaguchi's comment. The nuclear mean free path which we, air-shower people, measure is real nuclear mean free path for the air nucleus. I hope this is clear enough from our explanation of the means of derivation in the session of EAS. That is, what we can measure with EAS is the collision mean free path of the primary particle in the air. Certainly there is an ambiguity because of possible mixing of heavy nuclei. However, except this, the value (100± 10) g/cm² is not much affected by other ambiguities, like elasticities etc.

Fretter, W.B.: Excited nucleons which emit π^0-mesons have been observed in interactions of 11 GeV negative pions at CERN. The struck nucleon emerges with low energy in the laboratory system accompanied by one or more γ-rays also of low energy coming from the decay of π^0-mesons emitted by the excited struck nucleon. Charged pions are also sometimes observed in a similar way. This seems to be a fairly common process.

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III-7-16. The Role of Hyperons in Extensive Air Showers and Other High Energy Cosmic Ray Phenomena

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The development and the structural features of air showers depend critically on the properties of strongly interacting particles in the energy range above a few times 10^{11} eV. The largest available accelerators are now approaching this energy region so that some of the more recent laboratory results are applicable to the interpretation of cosmic ray phenomena in air showers without major extrapolations.

Experiments conducted at CERN on the multiplicity of K-mesons with strangeness $S=+1$ and $S=-1$ in interactions produced by 25 GeV protons prove that between 0.2 and 0.6 hyperons must be produced per collision. From considerations of symmetry it follows that the particle which carries the largest fraction of the available energy away from the interaction is in 10% to 30% of the cases a hyperon rather than a nucleon.

Information obtained from the study of high energy cosmic ray jets suggests strongly that the fraction of these hyperons increases further with energy (approximately as fast as the multiplicity of other shower particles), and that it probably amounts to 70% at a primary energy of 10^4 GeV. This would indicate that hyperons and nucleons are represented among the high energy baryons emerging from the collision roughly in proportion to their respective statistical weights. However, even if the share of hyperons does not increase as fast as suggested by evidence derived from the study of jets, the arguments which follow remain valid.

In high energy interactions in air, the emerging hyperon has a chance to decay before undergoing a nuclear collision. The decay pion receives a fraction of the hyperon energy which depends on the angle of emission and averages 16% for Λ and 20% for Σ-hyperons. The energy going to this single delayed pion represents, therefore, a major fraction of the energy given to the pion component as a whole.

When the energy of the emerging baryon exceeds a few hundred Gev, the delayed pion carries more energy than directly produced pions. This effect becomes more marked for higher collision energies, because the laboratory energy of directly produced pions increases essentially in proportion to the square-root of the energy of the incident particle, whereas that of the decay pion increases linearly.

The energy band in which conditions for