Hydrodynamical Model and Inelasticity in Multiple Production of Particles.

C. Iso
Research Institute for Fundamental Physics, Kyoto University - Kyoto

M. Namiki
Department of Applied Physics, Waseda University - Tokyo

(ricevuto il 15 Settembre 1958)

The authors (1) presented a possible hydrodynamical description of expanding meson-nucleon clouds in the framework of quantum field theory, in which it is shown that such a description is useful if the relaxation time of clouds is very short compared with its diffusion time. Along this line of thought, one could justify the hydrodynamical model of clouds in the period of expansion. But Fermi-Landau's assumption of equilibrium for clouds in the earlier period is involved in other unknown matters.

Following Landau's idea of the hydrodynamical model, secondary interactions at relatively low energies play essential roles to determine the several important quantities; i.e. the ratio of the number of K-mesons to that of pions, the transverse momentum and also the energy spectrum. For, secondary interactions determine the space time distribution of the system, mainly depending on the temperature irrespective of the initial details. The multiplicity depends only on the temperature of the initial state but has little relation to interactions at extremely high energies in the initial period of collision. (Landau does not consider the dependence on the mechanism of collision to be represented through the impact parameter.) On the other hand one might expect an essential influence of the details of such interactions in the initial period of collision on the important parameter «inelasticity». There we are interested in a problem whether the inelasticity, that is the energy fraction of produced mesons, is mainly determined by the mechanism of collision or by the secondary interactions. Now Landau's model don't permit us to calculate the inelasticity because it handles a one-constituent fluid from the outset. In the present note, it is shown that one may calculate the inelasticity and obtain its values consistent with the experimental ones, under the assumption that the clouds can be represented by the model of a mixed fluid with two constituents, the meson- and nucleon-fluids, and that the front part of the fluid is mainly occupied by the nucleon con-

stuent at the end of the expansion. (Here we make use of Fermi-Landau's initial conditions, that is to say, we consider that at the start of the expansion nucleons and pions are in thermal equilibrium with a high temperature irrespective of initial details. We shall not discuss the relations between inelasticity and impact parameter.) The latter assumption will be discussed at the end of this note. From this point of view we intend to infer the possibility that the effect of the mechanism of collision on the inelasticity would be masked by the secondary interactions in the experimental data. It is, however, to be noted that such an effect must be discussed together with the initial conditions given by Fermi and Landau. We shall not enter in it.

In the previous work (2) we calculated the energy fraction \( a \) (\%) of the front part of the fluid, where a particle occupying the front is considered to be almost a pion. According to the above assumption, the front particle should be a nucleon. (The probability of finding pions is neglected there.) Thus the effective elasticity becomes

\[
\frac{ab}{(100 - a) + ab},
\]

\( b \) being the ratio of the energy of a front nucleon to that of a front pion. Now the energies \( E_N \) of a nucleon and \( E_\pi \) of a pion in the fluid with a temperature \( T \) are obtained by

\[
E_N = \varepsilon_{NN}/n_{NN} = \frac{T\Phi^*(Z_N)/F^*(Z_N)}{1/T},
\]

\[
E_\pi = \varepsilon_{\pi\pi}/n_\pi = \frac{T\Phi(Z_\pi)/F(Z_\pi)}{1/T},
\]

in the rest system of the fluid, where \( \varepsilon_{NN} \) and \( \varepsilon_{\pi\pi} \) are energy densities of the nucleon fluid and the meson fluid, and \( n_{NN} \) and \( n_\pi \) number densities of nucleons and mesons, respectively. \( \Phi, \Phi^*, F \) and \( F^* \) are slowly varying functions, defined by Belen'kij and Landau (2), of the variable \( Z_N = M/T \) or \( Z_\pi = m/T \), \( M \) and \( m \) being the masses of nucleon and pion, respectively.

At the final temperature \( T \approx m \) we get

\[
E_N \approx 8m, \quad E_\pi \approx 3.3m,
\]

and consequently

\[
b = E_N/E_\pi \approx 2.5.
\]

Using this value of \( b \), one obtains the inelasticity tabulated in Table I (2).

Now the Bristol group (3) considered that 20\% of the particles with larger values of energy be K-mesons or nucleons and the remaining 80\% be pions. They defined the inelasticity \( K'' \) by the energy fraction of the latter part. Their experiments show the decrease of this value \( K'' \) for the increase of the incident energy. Such an inelasticity \( K'' \) can be calculated in the hydrodynamical

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Energy of incident nucleon (in the L. system) & \( 10^{12} \) & \( 10^{14} \) & \( 10^{16} \) & \( 10^{18} \) eV \\
\hline
Inelasticity (in the C.M. system) & 20\% & 30\% & 45\% & 60\% \\
\hline
\end{tabular}
\caption{Table I.}
\end{table}


(*) Taking into account the possibility that front particles are other than nucleons, these values of the inelasticity give us its lower limits. Furthermore it is noted that values of the inelasticity in the C. M. system are nearly equal to those in the L. system if the angular distribution is sharp and the inelasticity has small values.