Proton-Proton Inclusive Spectra in the Thermodynamical Model(*)

J. LETESSIER and A. TOUSSI

_Institut de Physique Nucléaire, Division de Physique Théorique - Paris (**) (***)_

(ricervuto il 2 Marzo 1972; manoscritto revisionato ricevuto il 2 Maggio 1972)

**Summary.** — The formulae of the momentum spectra given by the thermodynamical model are modified when the «locality» of conservation laws is given different senses. We give the resulting modifications to the formulae of Hagedorn and Ranft. In contrast to the calculations of these authors we show that one velocity function \( F(\lambda) \) is enough to describe the kinematical part of the p-p inclusive reactions; we do not need their second velocity function \( F_2(\lambda) \), and thus we eliminate three free parameters. Furthermore, the number of the remaining parameters is reduced by other arguments and very good fits of the present experimental data are obtained.

**1. – Free-production momentum spectrum in the thermodynamical model.**

In the thermodynamical model (\(^1\^4\)), the pure thermodynamical part leads to a number of definite predictions that are directly and consistently derived from the basic hypotheses of the model. The most important of these predictions are the exponential growth of the hadronic mass spectrum and, connected to this, the existence of a limiting temperature \( T_0 \) (\(^*\^\*) \); \( g(m) \) grows like \( \exp\left[ m/T_0 \right] \).

(*) To speed up publication, the authors of this paper have agreed to not receive the proofs for correction.

(**) Laboratoire associé au CNRS.

(***) Postal address: Tour 16, 9 Quai Saint Bernard, 75-Paris (5ème).


(\(^*\^\*)\) The value of \( T_0 \) used in this paper is 160 MeV obtained in ref. (2) by fitting the hadronic mass spectrum.
But in order to compute the momentum spectrum of a particle in an inclusive reaction, one has to combine this thermodynamics with the kinematics of collective motion in the forward-backward direction. More precisely, the differential momentum spectrum of a particle with mass \( m \) in a co-ordinate system \( (\mathcal{R}) \) reads

\[
W^{(m)}(\mathbf{p}) \, d^3 p = \int_{-1}^{+1} F(\lambda) \, L^{(m)}(\lambda, \gamma_0) \left\{ f_m(p', T(\lambda)) \, d^3 p' \right\} \, d\lambda,
\]

where

\[
\lambda = \operatorname{sign} (\beta) \frac{\gamma - 1}{\gamma_0 - 1}, \quad \gamma = [1 - \beta^2]^{-\frac{1}{2}},
\]

is the « velocity » of a volume element of hadronic matter (a fireball) decelerated from \( \beta_0 \) (before the collision) to \( \beta \) (after the collision).

\( f_m(p, T(\lambda)) \) is the pure thermodynamical spectrum of a particle of mass \( m \) in the rest frame system of the fireball \( (\lambda) \) with temperature \( T(\lambda) \):

\[
f_m(p, T) \, d^3 p = \text{const} \frac{P^2 dP}{\exp\left[\sqrt{P^2 + m^2/T}\right] + 1}
\]

(— for bosons, + for fermions).

\( F(\lambda) \) is a velocity weight function in the direction of the collision axis, averaged over the whole history of the collision, over the interaction volume and over all impact parameters. This function is symmetrical in the \( p-p \) case and is normalized over the \( \lambda \) variation interval \((-1, +1)\):

\[
\int_{-1}^{+1} F(\lambda) \, d\lambda = 2.
\]

\( L^{(m)}(\lambda, \gamma_0) \) is the Lorentz operator which transforms the isotropic spectrum \( f_m(p', T(\lambda)) \) in the \( \lambda \)-frame (i.e. rest frame of the fireball \( (\lambda) \)), into the spectrum seen in the \( (\mathcal{R}) \) frame.

2. – Restricted spectrum. Assumptions on the locality of the quantum number conserved laws.

The formula (1) gives the free-production spectrum, i.e. the spectrum when no conservation law is taken into account. It has to be modified in the two main situations described in the following Subsections 2'1 and 2'2.