HADRON THERMODYNAMICS IN RELATIVISTIC NUCLEAR COLLISIONS

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1. Introduction. The current interest[1] in the study of nuclear collisions at very high energies - especially nucleus-nucleus collisions at several GeV/nucleon - stems from the expectation that one can investigate under laboratory conditions the early beginings of our present universe. Thereby, one hopes to observe qualitatively new states of matter-such as density isomers, pion condensates, quark-gluon plasma (QGP), etc. The question whether the anticipated phase transition from hadron gas to QGP is a sharp or continuous one can only be answered through experiments devoted to the subsequent decay modes of this phase transition since the various theoretical models suffer in one way or other in their ability to pin point clear cut signals of this phase transition.

The search for QGP is basically a search for collective phenomena in strong interactions. Among them are the Cronin effeet, the EMC effeet, the production of secondaries with a kinectic energy above the kinematic limit in collisions of nucleons with targets of varying mass number, strange hadrons such as K, Λ, Σ and the leptons. However,from the data obtained, it is difficult to separate the purely QGP signals from the predictions of non-equilibrium QG-dynamics which can equally well explain the observed phenomena.

2. Relativistic Hadron Thermodynamics. The application of thermodynamics formalism to the study of high energy hadron-hadron central collisions has been in vogue for over forty years. What is now new is the use[2] of transformation laws of temperature and quantity of heat in the special relativistic thermodynamic formalism which preserves all the laws of classical thermodynamics by giving specific prescriptions in the

application of Lorentz transformation to the various thermodynamic quantities.

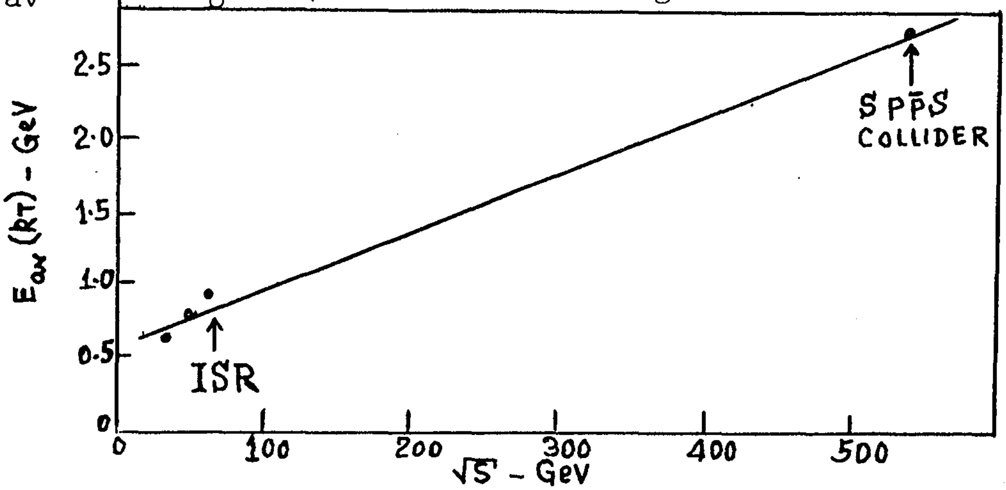
It is generally agreed that the entropy S is a Lorentz invariant and a unique answer is provided by statistical mechanics. In order to ensure the invariance of the entropy $dS = \delta Q/T$, the amount of (reversible) heat δQ and temperature T must transform in the same way. The problem comes in trying to preserve the first law $\delta Q = dU - \delta W$. The internal energy, U, <u>cannot</u> be considered as the fourth component of a four-vector as is done in the case of a mechanical point mass. The interpretation is to be modifild for hadrons considered as extended bodies. Statistically, the distinction between heat and work, though both represent some form of energy transfer, rests on the essentially disordered nature of energy which is regarded as heat. Also, the systems considered in thermodynamics are not isolated. Thermodynamic space and ordinary phase space must be treated in a similar Lorentz invariant way to be logically consistent.

3. <u>"Derivation" of law of Lorentz transformation of temperature.</u> In the literature there exist various "derivations" of the law of Lorentz transformation of temperature and other thermodynamic quantities. The transformation formulae for temperature accepted for over fifty years is the following

$$T = T_o(1- v^2/c^2)^{1/2}$$

and consequently $\delta Q = \delta Q_o(1-v^2/c^2)^{1/2}$. Where the subscript o refers to the rest system and quantities in the lab system without subscript and $\vec{v}$ is the velocity of the rest system with respect to the lab system. In the rest system all the energy is of a disordered form but, in the lab system, a fixed amount equal to v^2/c^2 of the net increase goes over into the ordered form, leaving $(1 - v^2/c^2)$ of the net increase as disordered energy. However, the statistical measure of disorder (i.e. entropy) is an invariant and this requires a lower temperature, compatible with a lower quantity of heat observed in the lab system[3].

4. Experimental 'evidence' from large P_T phenomena. Chiu et al[4] and Chew et al[5] used the "two-temperature" concept for large P_T phenomena and fited reasonably well the single particle inclusive cross-sections as a functions of P_T in a thermodynamically based statistical distribution. If we identify their values of $<kT_1>$ and $<kT_2>$ with the E_{av} in formula of ref. 2 ($E_{av} \sim \sqrt{s}/\mu\ T_o$), we find the following linear realationship.



5. Conclusions: Various phenomenological models based on statistical thermodynamical considerations have been used to fit the experimental data at high P_T to a two-temperature distribution. Whether this implies that the two-temperatures belong to two different reaction mechanisms, or consequences of Lorentz-contraction factor, or related in a fundamental way to the intrinsic 'thermodynamics of Space-Time' can only be revealed by further theoretical and experimental investigations of high P_T phenomena in extremely energetic hadron-hadron collisions.

6. References.

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