SCALING BEHAVIOUR OF ENTROPY IN MULTIPARTICLE PRODUCTION

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Abstract: In the present work multiparticle production in high-energy hadron – nucleus interaction has been studied in terms of particle entropy in $\pi^- - AgBr$ interactions at 350 GeV/c and 200 GeV/c. An approximate scaling behaviour of total produced entropy normalised to maximum rapidity in the centre of mass frame measured in different rapidity bins has been reported.

***Key Words*:** Hadron-nucleus interaction; Entropy scaling ; Hadron – nucleus interaction

1. INTRODUCTION

Entropy is important characteristic of systems with many degrees of freedom. It seems quite natural to use it in description of high energy multiparticle production processes. In particular, entropy of multiplicity distribution is an effective variable characterizing inelastic collisions with many particles produced.

Over the years, a debate took place about the mechanism and significance of entropy. Based on hydrodynamics, it has been argued that during the expansion phase, there might be a little change of entropy that was produced in the initial phase of interactions. After the interactions the entropy determines the abundances of the produced clusters.

A convenient means to study the energy dependence of multiplicity in an integrated form is provided by the so-called information-entropy. Information entropy of charged particle multiplicity distribution P_n is defined as [1]

$$S = -\sum_n P_n \ln P_n \qquad (1)$$

Here, P_n is the probability of having "n" produced particles in the final state such that, $\sum_n P_n = 1$. Information entropy is a measure of the uncertainty associated with a multiplicity distribution. A wide distribution gives more uncertainty and a larger value of S than a sharply peaked one.

Important properties of entropy are:

☞ It describes a general pattern of particle emission. The total entropy produced from ν statistically independent phase regions (*e.g.* Poisson distribution clans or super clusters) is the sum of the entropies of individual sources:

$$S = \sum_{i=1}^{\nu} S_i$$

☞ Distortion of the multiplicity scale leaves S invariant, so does insertion of zeros or mutual permutation. In particular, in full phase space, the entropy is the same when calculated from all charged particles or negatives (*i.e.* charged pairs) only.

Energy dependence of the entropy S in high energy collisions was first studied in [1]. Using multiplicity distribution of charged secondaries produced in *pp* and $\bar{p}\,p$ collisions in the energy range $\sqrt{s} \le 900\ GeV$, monotonous increase of S with center-of-mass energy $\sqrt{s}$ was found. At high energies ($\sqrt{s} \ge 20\ GeV$), the value of S increases linearly with $\ln\sqrt{s}$. For $\sqrt{s} > 20\ GeV$, the linearity

$$S = D_1 Y_m$$

with the maximum possible c.m.s. rapidity $Y_m = \ln(\sqrt{s}/m_\pi)$ of the hadrons produced is valid. Here m_π is the pion rest mass and D_1 is an energy independent constant, known as entropy per rapidity unit. Further, Tevatron data extend the validity of these findings up to $\sqrt{s} = 1.8\ TeV$ [2]. Entropy and its dependence on multiplicity and incident energy have been studied by several groups to understand the mechanism of particle production.

Here we have studied the pion entropy normalized to maximum rapidity ($\frac{S}{Y_m} = D_1$) in the center of mass frame as a function of the ratio of the width of pseudo rapidity interval $(\Delta\eta)$ to the maximum rapidity (Y_m) i.e. $\left(\frac{\Delta\eta}{Y_m}\right)$ in the multiparticle production of $\pi^- - AgBr$ interactions at 350 GeV/c and at 200 GeV/c.

2. EXPERIMENTAL DETAILS

In this analysis hadron-nucleus interaction data of π^--AgBr at 350 GeV/c has been used. A stack of G5 nuclear emulsion plate was exposed horizontally to a π^- beam at CERN with 350 GeV/c and at Fermilab with 200 *GeV/c*.

The emulsion plates were area scanned with a Leitz Metalloplan Microscope fitted with a semiautomatic scanning device, having a resolution along the X and Y axes of 1 μm while that along the Z axis is 0.5 μm . A sample of 569 events of π^--*AgBr* at 350 GeV/c and 350 events at 200 GeV/c were chosen, following the usual emulsion methodology for selection criteria of the events.

According to nuclear emulsion terminology [3], the particles emitted in high-energy interactions are classified as:

(a) Black particles: They are target fragments with ionization greater than or equal to 10 I_0 , I_0 being the minimum ionization of a singly charged particle. Their ranges are less than 3 mm. Their velocity is less than 0.3 c and their energy is less than 30 *MeV*, where c is the velocity of light in free space.

(b) Grey particles: They are mainly fast target recoil protons with energy up to 400 *MeV*. The ionization power of gray particles lies between 1.4 I_0 to 10 I_0. Their ranges are greater than 3 mm and they have velocities between 0.3 c to 0.7 c .

(c) Shower particles: They are mainly pions with ionization $\le 1.4\, I_0$. These particles are generally not confined within the emulsion pellicle.

3. RESULT AND DISCUSSION

We have calculated the probability P_n in both the interactions for varying values of $\Delta\eta$ .Using the values of P_n the entropy of the pions in each value of $\Delta\eta$ has been computed using relation (1) . We have also find out the maximum pseudo-rapidity value of pions produced in the center of mass system following the relation given by Simak et al [1] $Y_m = \ln\left[\frac{\sqrt{s}}{m_\pi}\right]$ where $\sqrt{s}$ is the centre of mass energy and m_π is the rest mass of pion. Then we have calculated $\frac{S}{Y_m}$ for every $\frac{\Delta\eta}{Y_m}$ for both the interactions for all $\Delta\eta$ .. In the Fig. 1 a plot of $\frac{S}{Y_m}$ against $\frac{\Delta\eta}{Y_m}$ for $\pi^- - AgBr$ interactions at 350 GeV/c and at 200 GeV/c are shown. From the figure it is observed that the value of $\frac{S}{Y_m}$ saturates at $\frac{\Delta\eta}{Y_m} = 0.8$ for both the interactions. It is observed that the values of $\frac{S}{Y_m}$ for both the

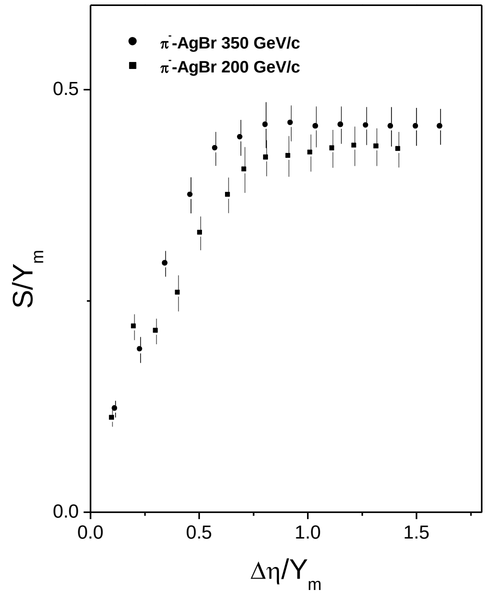

Figure 1: Plot of $\frac{S}{Y_m}$ against $\frac{\Delta\eta}{Y_m}$

interactions saturates approximately at the same value of $\frac{\Delta\eta}{Y_m}$. The errors shown in the figure are purely statistical. Considering the error bars it may be concluded that the data exhibits a scaling property of the quantity $\frac{S}{Y_m}$. for hadron-nucleus interactions.

4. CONCLUSIONS

In this analysis the particle production data at SPS energy give an indication of scaling properties for the total produced entropy normalized to the maximum rapidity mesured in different rapidity bins. The following interesting features are revealed from the present investigation: -

1. The entropy for the pion data in hadron-nucleus interactions exhibit a scaling property.
2. The experimental data rapidly saturates approximately at $\frac{\Delta\eta}{Y_m} = 0.8$ for both the interactions irrespective of beam energy.
3. The indication of the scaling behaviour signifies that the entropy per unit maximum rapidity is approximately an energy – independent quantity.

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