Entropy scaling in hadron-nucleus interactions

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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.

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, 2]

$$S = -\sum_n P_n \ln P_n$$

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 $\sqrt{s}$ ≤ 900 *GeV*, monotonous increase of S with center-of-mass energy $\sqrt{s}$ was found. At high energies ($\sqrt{s}$ ≥ 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* [3]. 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.

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. 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. 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. 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 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.

Thus we conclude that (a) the entropy for the pion data in hadron-nucleus interactions exhibit a scaling property. (b) the experimental data rapidly saturates approximately at $\frac{\Delta\eta}{Y_m}$= 0.8 for both the interactions irrespective of beam energy.

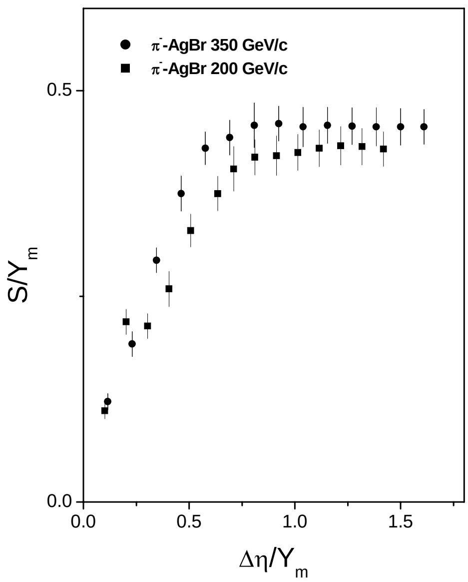

Fig.: Plot of $\frac{S}{Y_m}$ against $\frac{\Delta\eta}{Y_m}$

References

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