Fluctuations and the clustering of color sources

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Abstract. We present our results on multiplicity and $p_T$ fluctuations at LHC energies in the framework of the clustering of color sources. In this approach, elementary color sources -strings- overlap forming clusters, so the number of effective sources is modified. We find that the fluctuations are proportional to the number of those clusters.

Non-statistical event-by-event fluctuations in relativistic heavy ion collisions have been proposed as a probe of phase instabilities near de QCD phase transition. The transverse momentum and the multiplicity fluctuations have been measured at SPS and RHIC energies. These fluctuations show a non-monotonic behavior with the centrality of the collision: they grow as the centrality increases, showing a maximum at mid centralities, followed by a decrease at larger centralities. Different mechanisms have been proposed in order to explain those data. Here, we will apply the clustering of color sources. In this approach, color strings are stretched between the colliding partons. Those strings act as color sources of particles which are successively broken by creation of $q\bar{q}$ pairs from the sea. The color strings correspond to small areas in the transverse space filled with color field created by the colliding partons. If the density of strings increases, they overlap in the transverse space, giving rise to a phenomenon of string fusion and percolation \cite{1}. Percolation indicates that the cluster size diverges, reaching the size of the system. Thus, variations of the initial state can lead to a transition from disconnected to connected color clusters. The percolation point signals the onset of color deconfinement.

These clusters decay into particles with mean transverse momentum and mean multiplicity that depend on the number of elementary sources that conform each cluster, and the area occupied by the cluster. In this approach, the behavior of the $p_T$ \cite{2} and multiplicity \cite{3} fluctuations can be understood as follows: at low density, most of the particles are produced by individual strings with the same transverse momentum $<p_T>_1$ and the same multiplicity $<\mu_1>$, so fluctuations are small. At large density, above the critical point of percolation, we have only one cluster, so fluctuations are not expected either. Just below the percolation critical density, we have a large number of clusters formed by different number of strings $n$, with different size and thus different $<p_T>_n$ and different $<\mu>_n$ so the fluctuations are maximal.

The variables to measure event-by-event $p_T$ fluctuations are $\phi$ and $F_{p_T}$, that quantify the deviation of the observed fluctuations from statistically independent
particle emission:
\[
\phi = \sqrt{\frac{< Z^2 >}{< \mu >}} - \sqrt{< z^2 >},
\]
where \( z_i = p_{T_i} - < p_T > \) is defined for each particle and \( Z_i = \sum_{j=1}^{N_i} z_j \) is defined for each event, and
\[
F_{p_T} = \frac{\omega_{data} - \omega_{random}}{\omega_{random}}, \quad \omega = \frac{\sqrt{< p_T^2 >} - < p_T >^2}{< p_T >}.
\]
Moreover, in order to measure the multiplicity fluctuations, the variance of the multiplicity distribution scaled to the mean value of the multiplicity has been used. Its behavior is similar to the one obtained for \( \Phi(p_T) \), used to quantify the \( p_T \)-fluctuations, suggesting that they are related to each other. The \( \Phi \)-measure is independent of the distribution of number of particle sources if the sources are identical and independent from each other. That is, \( \Phi \) should be independent of the impact parameter if the nucleus-nucleus collision is a simple superposition of nucleon-nucleon interactions.

In Fig. 1 we present our results on \( p_T \) fluctuations at LHC. Note that the increase of the energy essentially shifts the maximum position to a lower number of participants [2]. In Fig. 2 we show our values for the scaled variance of negatively charged particles at SPS, RHIC and LHC energies.

Summarizing: the \( p_T \) and multiplicity fluctuations are due in our approach to the different mean \(< p_T >\) and mean multiplicities of the clusters, and they depend essentially on the number of clusters. In other words, a decrease in the number of effective sources leads to a decrease of the fluctuations.

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[3] L. Cunqueiro, E. G. Ferreiro, F. del Moral and C. Pajares, Phys. Rev. C 72, 024907 (2005) arXiv:hep-ph/0505197.