Academia Journal of Scientific Research 8(12): 383-386, December 2020
DOI: 10.15413/ajsr.2020.0114
ISSN 2315-7712

Research Paper

Some evidences of multiplicity fluctuations in relativistic nuclear collisions and Neural Networking (N-N) model

Accepted 7th February, 2019

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ABSTRACT

This study attempted to investigate some features of non-thermal phase transitions during the relativistic heavy ion collisions. The collisions that occurred were a beam of ^{28}Si (projectile) hits the heterogeneous mixture of nuclear emulsion (fixed target) @ energy 14.6A GeV and we recorded 951 events of relativistic nuclear collisions. Thereafter, for the final statistical study, we made three different groups of data sets such as ^{28}Si+CNO, ^{28}Si+Emulsion and ^{28}Si+AgBr. The results of the experiment was compared with neural network (N-N) model and a good agreement found between the theory and experiment of relativistic heavy ion collisions.

Key words: Intermittency, Scaled Factorial Moments (SFMs) and Non thermal Phase transition.

INTRODUCTION

There is no obvious physical reason in the Big Bang theory to the questions raised in this study. But one thing is quite certain, that according to laws of nature, we are aware that very small changes in any of these key parameters would have resulted in a grossly different universe. So the chances of life permitting the universe would be vanishingly small as compared to all theoretically possible universes. Therefore, this study explains that the high energy hadron-nucleus, hadron-hadron and nucleus -nucleus collisions have a long history and an enormous literature: a very complete review contains more than a thousand references (Fredriksson et al., 1987). The multiplicity fluctuations or multiplicity correlations are considered to be prove of the hot and dense matter generated in high-energy heavy ion collisions theoretically (Gyulassy, 1984; Stephanov et al., 1999; Hwa, 1990) and have been extensively studied experimentally (Hwa, 1996; Hwa and Cao, 1997). In particular, we expect that fluctuations of dynamical origin are useful for screening of models for the evolution of the matter and understanding of the mechanism in multi-particle interactions (Hwa and Zhang, 2002; Ahmad and Ahmad, 2006).

The heavy-ion collisions at ultra high energies follow a path between the two extremes, increasing both the temperature and baryon density. It may be verified in future experiments that the energy densities ~ 1-3 GeV/fm^3, equivalent to a temperature T_c ~ 150-200 MeV (Fredriksson et al.,1987; Gyulassy, 1984; Stephanov et al., 1999; Hwa, 1990; Ahmad and Ahmad, 2006; Ahmad, 2010; Bjorken, 1983; Hwa and Nazirov, 1992; Hwa and Pan, 1992; DeWolf et al., 1996) or baryon density $\rho_c \approx$ 5-10 times nuclear matter density can indeed be reached in heavy ion collisions.

In contrast, if there are fluctuations of dynamical origin in the initial stage of the multiparticle production and if those traces remain in some observables, they must give some important information on the dynamics of quark and gluon mater at the initial stage of the reaction (Trainor and Ray, 2011; Gavin and Moschelli, 2012; Bozek and Broniowski, 2017). Recently, the ALICE Collaboration has published data on event-by-event fluctuation of charged particles in p + p and Pb+Pb collisions at Large Hadron Collider (LHC) energies (Abelev et al., 2014; Heckel, 2015; Heckel, 2011). Note that the Bose-Einstein correlations (BEC) of gluons generated in the early stage of the hadronic collisions can

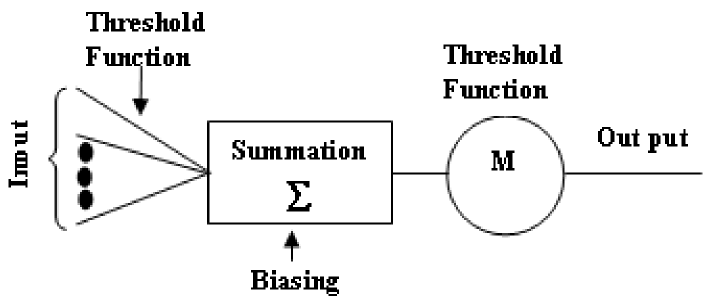

Figure 1: A Schematic diagram of Neural Network (N-N) Model.

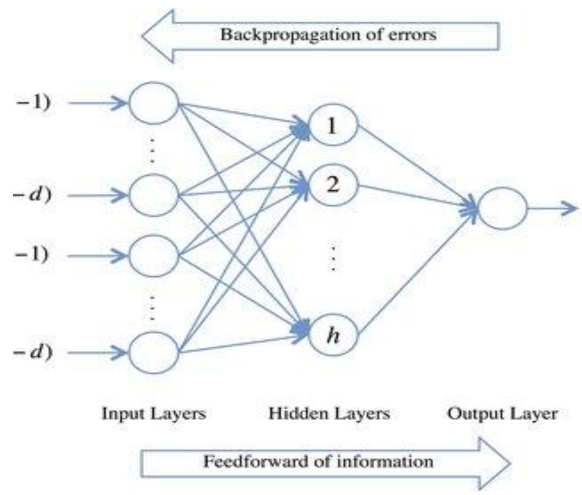

Figure 2: A sketch of multilayer Neural Network (N-N) Model.

be regarded as a possible origin of such fluctuations.

Various workers in the field of theory and experiment have proposed different methods to identify the existence of non-statistical fluctuations. Bialas and Peschanski (1986) and Bialas and Peschanski (1988) were the first to introduce a perfect method known as scaled factorial moments (SFMs) to study the non-statistical fluctuations in the relativistic nuclear collisions. In such nuclear collisions, the power law behavior of SFMs is known as intermittency phenomenon.

The recent studies of relativistic heavy-ion collisions are to be given extensive scientific attention. This is for two reasons: First, they propose an exclusive testing ground for newly developed methods to study the behavior of strongly interacting quantum systems with finite particle number far from the ground state. Secondly, one hopes that the hot and dense nuclear matter can be extracted from the experimental data. This knowledge is essential for an understanding of the collapse of supernovae, for neutron-star stability, and for the onset of a possible phase transitions from hadron matter to the quark-gluon plasma (QGP).

In the world of technology where theory and experiment agreed completely and where there were no experimental acceptance cuts, the technique named neural network (N-N) model would be a perfect tool to determine some experimental observables and/or facts. In high energy physics, the neural network (N-N) model / technique is often used for identification of particles, reconstruction of particle tracks and classification of decays pattern quite successfully.

Neural Network (N-N) model

Neural network (N-N) model is nothing but an approximate functional fitting to any experimental data. For this purpose, one wants to construct a mapping "M" between a set of observable quantities S_i (where i = 1, . . . , n) and category variable "N" by fitting "M" to a set of "Q" known "training" samples $(S_i^{(p)}, N_k^{(p)}, i = \cdots . n; k = 1 \ldots r)$ $(p = 1 \ldots . Q, N_k \in N)$. Once the parameters in "M" are fixed, and then it uses for parameterization to interpolate and find the category of "test" samples not included in the "training" set. A schematic diagram of N-N Model has been depicted in Figure 1.

A typical multilayer neural network (N-N) programming model is also represented in Figure 2. It consists of an input layer and an output layer with various numbers of nodes, so called neurons in each layers. In the present

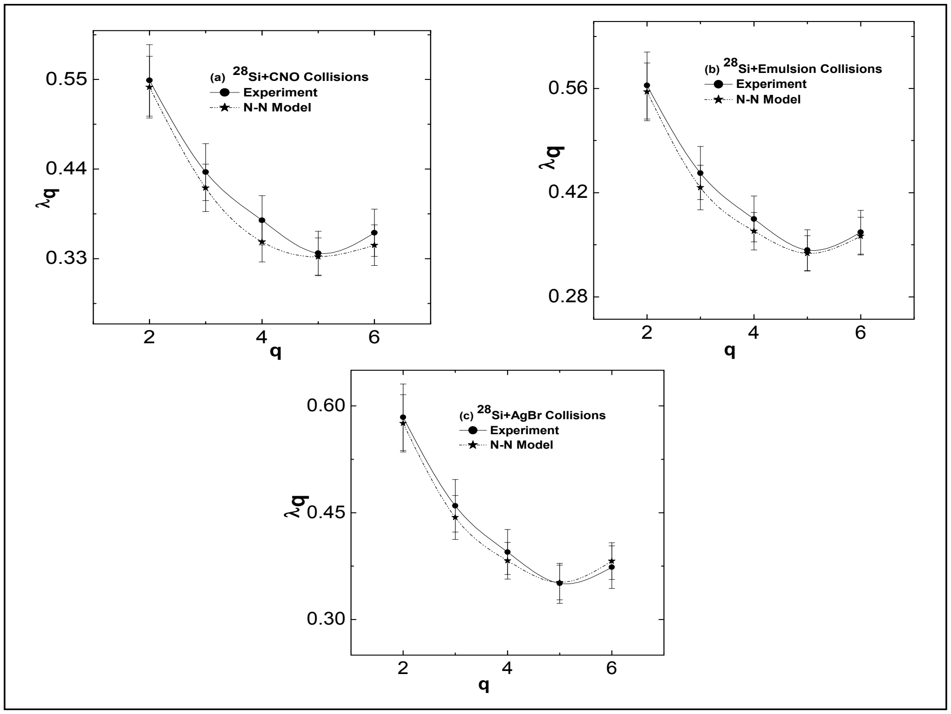

Figure 3 (a-c): Variation of λ_q as a function of q for all data sets along with N-N model.

study, we used the multilayer perceptron program developed in the MATLAb.

Here, we have applied three inputs parameters: the lab momentum(P_L), the mass numbers of the projectile nuclei (A), and the average values of pseudo-rapidity ($<\eta>$). After the completion of computer programming, we got one output parameter that is simulated values of the pseudo-rapidity (η) corresponding to the experimental data.

RESULTS AND DISCUSSION

It has been observed (Ahmad and Ahmad, 2006; Ahmad, 2010; Bialas and Peschanski, 1986) that if the dynamics of intermittency is due to self-similar cascading, then there is a possibility of observing a non-thermal phase transition, which is believed to occur during the collision. If such a non-thermal phase transition is present, then the function: $\lambda_q = (\alpha_q + 1)/q$, should have a minimum at certain value of q = q_c, where q_c is some minimum point in the distribution (Ahmad and Ahmad, 2006; Ahmad, 2010). The region with $q < q_c$ is dominated by numerous small fluctuations, whereas the region with $q > q_c$ is due to rarely large fluctuations. This situation can easily be compared with a mixture of "liquid" of large number of small fluctuations and a "dust" consisting of few grains of very large density.

A complete mathematical description related to the present statistical analysis has been given in our recent study accepted for final publications in the Urk. J. Phys. 2013 (Gyulassy, 1984). From both type of Pseudo-rapidity (η) values (Exp. & simulated by N-N model), first we applied it to Scaled Factorial Moments (SFMs) for the intermittency. By doing this we get the values of intermittency index, α_q, which is the slope values of graphs plotted between the $\ln<F_q>^{corr}$ Vs. ln M for all the data sets. These plots are also not mentioned here. With the knowledge of intermittency index, α_q, the possibility of detecting a non-thermal phase transition can be obtained by relation: $\lambda_q = (\alpha_q + 1)/q$, where q is the order of SFMs (q = 2-6).

It has been observed (Gyulassy, 1984) that if the dynamics of intermittency is due to self-similar cascading, then there is a possibility of observing a non-thermal phase transition, which is believed to occur during the relativistic heavy ion collisions. The variation of λ_q as a function of q for all data sets along with the prediction of N-N model has been shown in Figure 3(a-c). From the figure, it may be noted that no clear-cut minimum value of λ_q for certain value of q has been observed in the present experimental work as it is reported by other workers. However, a weak intermittency effect has been found in ^{28}Si+AgBr and ^{28}Si+Em collisions (experimentally along with N-N model). To get more unambiguous evidence, the analysis should be done up to q = 8 with large statistics at high energies and with different projectiles.

CONCLUSION AND RECOMMENDATIONS

Finally, The region with $q < q_c$ is dominated by numerous small fluctuations, whereas the region with $q > q_c$ is due to rarely large fluctuations. This situation can easily be compared with a mixture of "liquid" of large number of small fluctuations and a "dust" consisting of few grains of very large density. We observed that there is no clear-cut minimum value of λ_q for certain value of q has been observed within the limit $2 \leq q \leq 6$ as reported by other studies. However, a little deviation of the experimental data from the "no intermittency" line ($\alpha_q = 0$) indicates the presence of a weak intermittency effect in the present data.

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Cite this article as:

Ahmad MA, Victoria ADC, Baker JH, Lyashenko VV (2020). Some evidences of multiplicity fluctuations in relativistic nuclear collisions and Neural Networking (N-N) model. Acad. J. Sci. Res. 8(12): 383-386.

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