Wavelet analysis in ^{28}Si-Ag/Br interaction at 14.5A GeV

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In various branches of science and engineering the wavelet decomposition technique is an efficient way of extracting useful signals from a highly noisy spectrum [1]. Recently, the technique has been applied to analyze the multiparticle production data in high-energy heavy-ion collisions [2]. The objective is to search for unusual structures, if there is any, in the angular distribution of emitted particles. In this short report we present a preliminary result on the wavelet analysis of the pseudorapidity (η) distribution of singly charged particles produced in ^{32}Si-Ag/Br interaction at 14.5A GeV [3]. The experimental measurement is compared with a model code based on the Ultra-relativistic Quantum Molecular Dynamics (UrQMD) [4]. The UrQMD events are subsequently modified with a charge reassignment algorithm implemented as an 'after burner' to incorporate the Bose-Einstein correlation (BEC) among identical bosons [5]. This modified data set (UrQMD+BEC) is also used for comparison with the experiment.

The wavelet transform $W_\Psi(a,b)$ of a function $f(x)$ is given by [6]

$$W_\Psi(a,b) = \frac{1}{\mathcal{N}_\Psi}\int_{-\infty}^{+\infty} f(x)\,\Psi_{a,b}(x)dx, \quad (1)$$

where $\Psi_{a,b}(x) = a^{-1/2}\Psi\left(\frac{x-b}{a}\right)$ is the mother wavelet, a is the scale parameter, b is the translation parameter, and $\mathcal{N}_\Psi$ is a normalization constant. The second derivative $g_2(x) = (1-x^2)\exp(-x^2/2)$ of Gaussian function, also known as the Mexican hat, is conventionally taken as the mother wavelet $\Psi(x)$. For multiparticle emission data $f(x)$ can be the η-distribution $f(\eta)$ of the event sample,

$$f(\eta) = \frac{dn}{d\eta} = \frac{1}{N}\sum_{i=1}^{N}\delta(\eta-\eta_i), \quad (2)$$

N being the total number of particles present in the sample. The wavelet transform of distribution (2)

$$W_\Psi(a,b) = \frac{1}{N}\sum_{i=1}^{N} a^{-1/2}\Psi\left(\frac{\eta_i - b}{a}\right) \quad (3)$$

represents the probability to observe a particle at $\eta = b$ and scale a. In FIG. 1 the g_2-spectra of the η-distribution of all three event samples mentioned above are shown at four different values of the scale parameter a. The preferred η-values of the produced particle group (cluster) are identified by the positions of the maxima, while a characterizes the cluster size. At small scales ($a = 0.1$ and 0.2) one can see some structures. However, with increasing a each spectrum smooths out to the mother wavelet. Neither the UrQMD nor the UrQMD+BEC data can reproduce the fluctuating pattern of

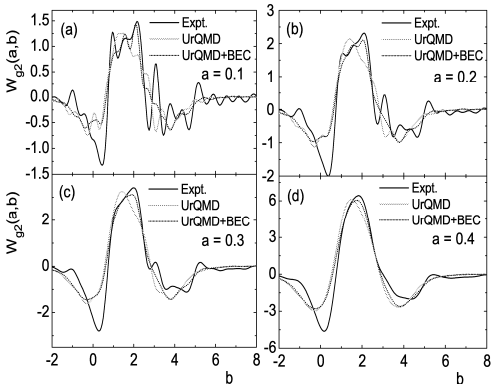

FIG. 1: g_2 wavelet pseudorapidity spectra for different values of the scale parameter a.

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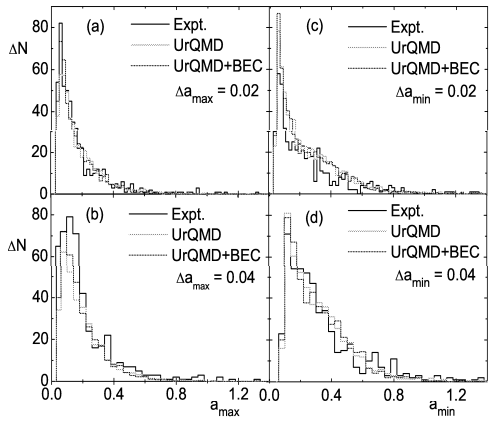

FIG. 2: Distributions of the maximum (left) and minimum (right) positions of the scalograms on a.

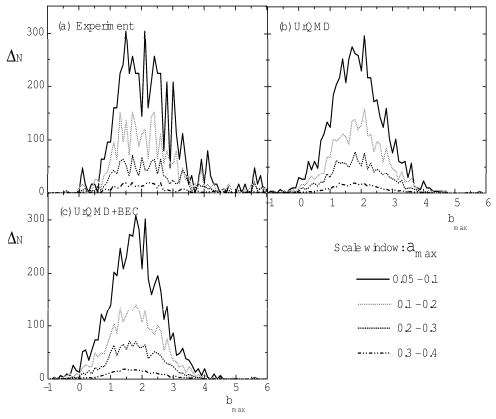

FIG. 3: The $b_{\max}$ distributions of (a) the experiment, (b) the UrQMD and (c) the UrQMD+BEC events. The distributions, in the different scale windows, are shifted to avoid mutual overlapping.

the experiment. Even the small fluctuations that are present in the simulated data, are washed out at a faster rate than the experiment. These diagrams suggest that the cluster size $a \approx 0.2$ in the experiment and it is probably even smaller in the simulation.

To examine the preferred scale of particle emission, we study the local maxima (minima) of the scalograms on an event-by-event basis. The scalogram for a single event is defined as $E_W(a) = \int \{W_\Psi(a,b)\}^2 db$. Its local maxima (minima) indicate the relevant scales. Position distribution of the local maxima (minima) in the scalograms of all the analyzed events is shown in FIG. 2 at two different bin widths $\Delta a_{\max}(\Delta a_{\min}) = 0.02$ and 0.04. One can see that for $\Delta a_{\max} = 0.04$, there are some significant experimental excesses over the simulated data in the $a_{\max}$ distribution at around $a_{\max} \sim 0.2$. Otherwise, we do not observe any noticeable difference between the experiment and the simulation.

Distribution of the local maxima of $W_\Psi(a,b)$ in b, which reflects the preferred η-values of particle emission, are shown in FIG. 3(a)–(c). Each distribution is obtained in different scale windows a_{max}, and to avoid mutual overlapping of the plots arbitrary scales are used. Only the shape of the distribution is relevant here. Once again in comparison with the fluctuating pattern of the experiment, the simulated distributions are quite smoothly varying. We conjecture that in the central $\eta = 1.0 - 3.0$ region clusters of size $0.05 - 0.2$ in η units are present in the experimental data.

Acknowledgments

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