INTERMITTENCY IN Au + Au COLLISIONS BELOW 1A GeV. CAN IT BE REPRODUCED BY IQMD SIMULATIONS?*

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Results of the intermittency analysis of experimental data obtained with the FOPI detector and the analysis of events simulated by the IQMD model for Au + Au collisions at 600A and 800A MeV are presented. The method of horizontal normalized scaled factorial moments was used. The intermittency analysis for charge-, rapidity- and azimuthal angle observables has shown that results of IQMD simulations with hard equation of state, momentum dependent interactions and standard nucleon–nucleon interaction cross section reproduce experimental data better than simulations with other sets of parameters.

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Intermittency is a statistical concept used in studying fluctuations and correlations in distributions. It is a feature which can be observed in multiparticle distributions. We applied this concept in analysis of Au + Au collisions studied at GSI Darmstadt with the FOPI detector [1]. The presence of the intermittency signal in these collisions has already been reported in our earlier publications [2–4]. To search for intermittency, we used the method of horizontal normalized scaled factorial moments (HNSFMs) of rank i [6], defined as

$$\langle F_i^{\delta X}\rangle = \frac{\Big\langle \sum_{m=1}^{M} k_m(k_m-1)\dots(k_m-i+1)\Big\rangle_{\rm ev}}{\langle N\rangle^i_{\rm ev}} \times \frac{(N^{\rm INC})^i}{\sum_{m=1}^{M}(k_m^{\rm INC})^i}\,, \qquad (1)$$

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where δX is the bin width of the distribution of the variable X, M — the number of bins, k_m — the number of particles in the m-th bin in an event, N — the multiplicity in an event, k_m^{INC} — the number of particles in the m-th bin of the inclusive spectrum, N^{INC} — the total number of particles in the inclusive spectrum, and the symbol $\langle\ \rangle_{\mathrm{ev}}$ denotes averaging over the sample of events.

For pure Poissonian fluctuations of bin occupancies the HNSFM values are close to 1. For Poissonian and in addition dynamical fluctuations the corresponding values of HNSFM become greater than 1. Intermittency implies a characteristic power-law dependence of normalized scaled factorial moments on the bin size

$$\langle F_i^{\delta X} \rangle \propto (\delta X)^{-\alpha_i} \,. \tag{2}$$

It is of great importance to set stringent centrality selection criteria since mixing of events, corresponding to different impact parameters, generates a trivial intermittent behavior. Two selection criteria were used: *(i)* high multiplicity (PM) and *(ii)* high transversal-to-longitudinal energy ratio (ERAT) [7]. In the intermittency analysis we used events which fulfill both criteria simultaneously.

Results of the analysis of experimental data were compared to predictions of the IQMD [5] model. The Isospin Quantum Molecular Dynamics model is a n-body theory which simulates heavy ion collisions at intermediate energies on an event-by-event basis. Consequently, the model-simulated events can be analyzed with the same method as those used in the analysis of exclusive experimental data. To estimate apparatus effects, the GEANT [8] simulation tool was used.

Results for the charge-, rapidity-, and azimuthal angle observables published in Ref. [3] have demonstrated that the experimentally observed non-statistical fluctuations in the rapidity- and azimuthal angle distributions cannot be satisfactorily explained by the IQMD model with a standard set of parameters, while only part of the observed effect can be related to apparatus effects. In the azimuthal angle analysis two regions with different slopes of the dependence of the horizontal normalized scaled factorial moments on the width $\delta\phi$ were found. IQMD calculations have revealed that non-statistical fluctuations in large bins can be attributed to the effect of non-isotropic emission patterns following randomly oriented reaction plane [3].

In the present article we report recent results of an analysis carried out for events generated with the IQMD code with various input parameters characterizing the equation of state (EoS) and different assumptions concerning nucleon–nucleon cross sections (σ_{nn}) and momentum dependent interactions. The IQMD calculations were done assuming alternatively "hard" (H) EoS ($K = 380$ MeV), "soft" (S) EoS ($K = 200$ MeV) and "hard" or "soft"

EoS with momentum dependent interactions, (HM) or (SM), respectively. In addition, the nucleon–nucleon interaction cross section was assumed to be either half ($0.5\sigma_{nn}$), double ($2\sigma_{nn}$) or exactly equal to the free nucleon–nucleon interaction cross section (σ_{nn}).

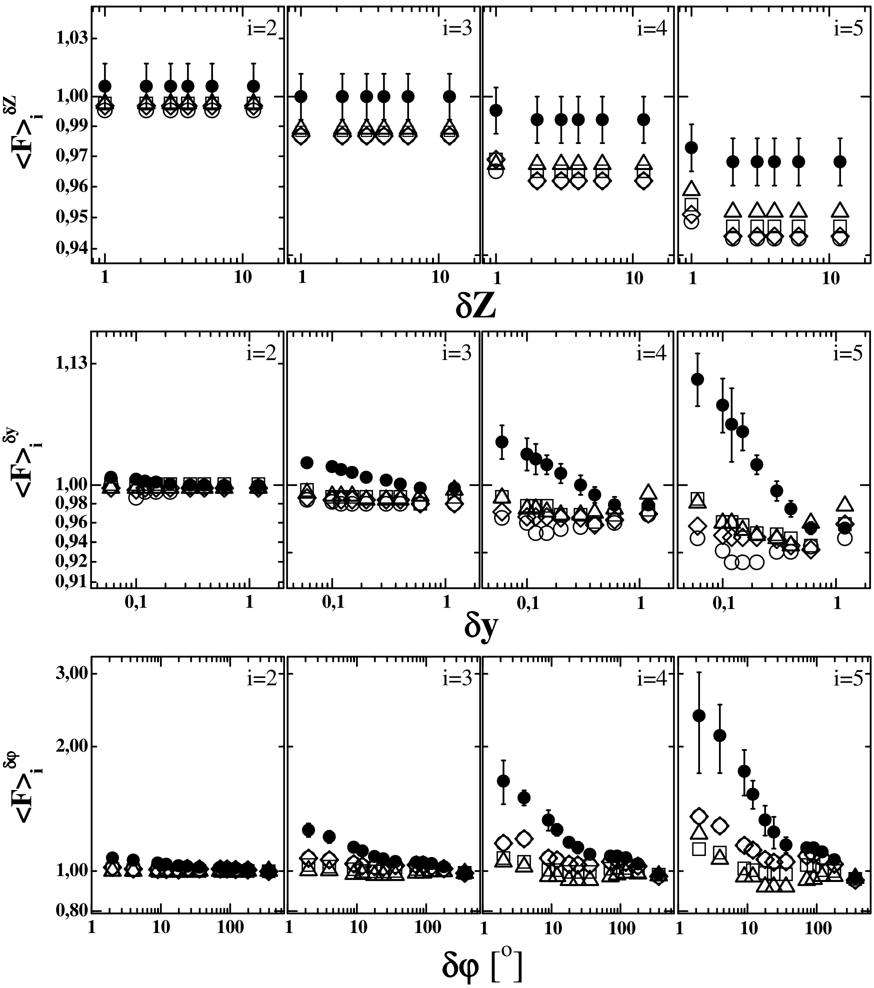

Fig. 1. Values of HNSFMs of rank $i = 2$–5 (left to right) as a function of the bin width, for central Au + Au collisions, at 800A MeV beam energy. Black dots represent experimental results, squares — IQMD with H EoS, triangles — IQMD with S EoS, diamonds — IQMD with SM EoS and open circles IQMD with HM EoS.

In Fig. 1 values of HNSFMs of rank $i = 2$–5, calculated for charge, rapidity and azimuthal angle observables are presented as a function of the bin width, for central Au + Au collisions, at 800A MeV beam energy. Simulations were done for different parameters of EoS. Black dots represent experimental results, squares — IQMD with H EoS, triangles — IQMD with S EoS, diamonds — IQMD with SM EoS and open circles IQMD with HM EoS.

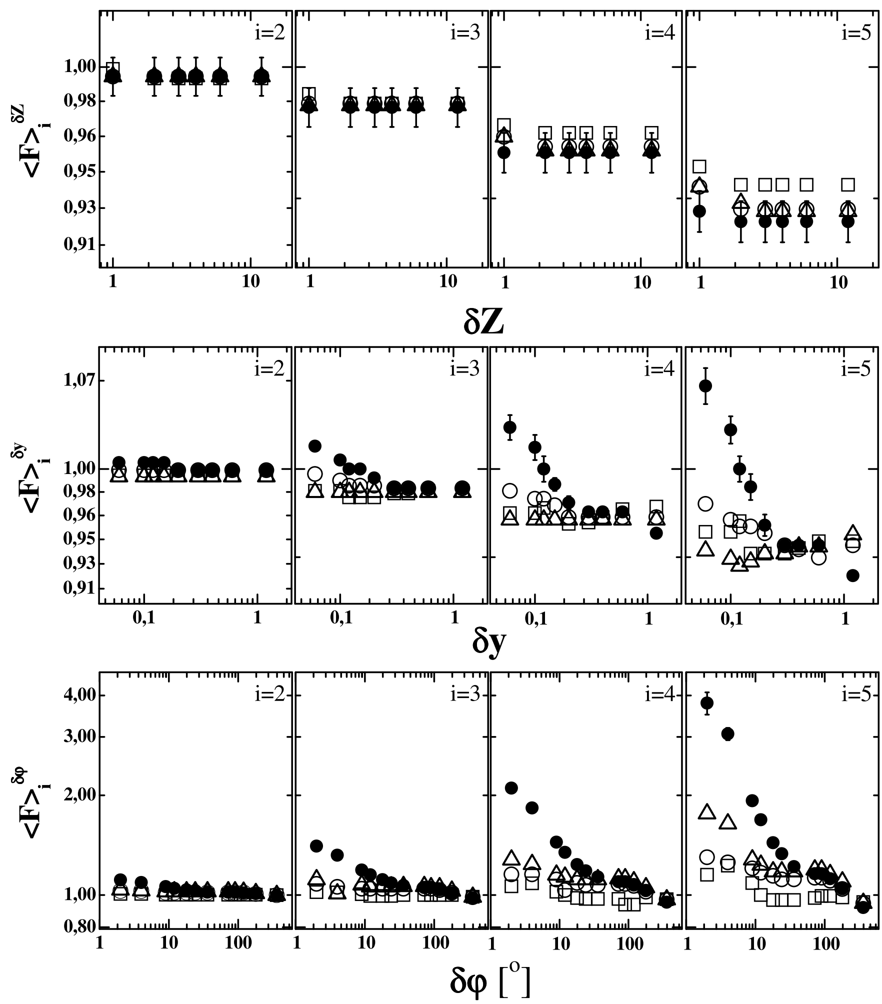

Fig. 2. Values of HNSFMs of rank $i = 2$–5 (left to right) as a function of the bin width, for central Au + Au collisions, at 600A MeV beam energy. Black dots represent experimental results, squares — IQMD with $0.5\sigma_{nn}$, triangles — IQMD with $2\sigma_{nn}$ and open circles IQMD with standard free nucleon–nucleon interaction cross section σ_{nn}.

In Fig. 2 values of HNSFMs of rank $i = 2$–5, calculated for charge, rapidity and azimuthal angle observables are presented as a function of bin width, for central Au + Au collisions, at 600A MeV beam energy. Simulations were done for different values of nucleon–nucleon interaction cross section. Black dots represent experimental results, squares — IQMD with $0.5\sigma_{nn}$, triangles — IQMD with $2\sigma_{nn}$ and open circles — IQMD with standard free nucleon–nucleon interaction cross section σ_{nn}.

The statistical uncertainties of both experimental and simulated points shown in Fig. 1 and Fig. 2 were obtained by dividing the data into subsets (16 or 8) and estimating the resulting dispersion of HNSFM values.

As seen from Fig. 1 and Fig. 2, different parameters of the equation of state and different values of the nucleon–nucleon interaction cross section, treated as simulation parameters, affect mainly the strength of intermittency. It seems that the exponential dependence of HNSFM on bin size is not significantly affected by these changes. Results of IQMD simulations with hard equation of state, momentum dependent interactions and standard nucleon–nucleon interaction cross section reproduce experimental data better than simulations with other sets of parameters. However, the reaction mechanism implemented in the IQMD model can only partly explain the intermittency signal found in the experimental data.

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