INTERMITTENCY ANALYSIS IN MOMENTUM SPACE IN Au+Au REACTIONS AT 150–800 AMeV*

M.M. Smolarkiewicz, M. Kirejczyk, B. Sikora
K. Siwek-Wilczyńska and I.J. Soliwoda

Institute of Experimental Physics, Warsaw University
Hoża 69, 00-681 Warszawa, Poland

(Received December 4, 2001)

Results of a search for intermittency signal in Au+Au collisions at 150–800 AMeV beam energy are presented. The method of horizontal normalised scaled factorial moments was applied. Data from the FOPI detector at GSI Darmstadt were analysed. No distinct intermittency signal was found in rapidity and charge distributions. Intermittency occurred in azimuthal angle distributions. The signal found in experimental data can be only partly accounted for by the influence of the apparatus and cannot be currently explained by the dynamical model IQMD.

PACS numbers: 25.70.Pq

The analysis of the event-by-event fluctuations in nuclear collisions has been the subject of our earlier research [1, 2]. Here we present results of the search for intermittency signal in Au+Au collisions at 150–800 AMeV beam energy and compare them to model predictions.

Intermittency is used in studying fluctuations and correlations in distributions. It is a feature which may be observed in multiparticle distributions. In the search for intermittency we used the method introduced in 1986 by Białas and Peshansky [3]. They proposed to study normalised scaled factorial moments. The so-called *horizontal normalised scaled factorial moment of rank i* is defined as

$$\left\langle F_i^{\delta X} \right\rangle = \frac{\left\langle \sum\limits_{m=1}^{M} k_m(k_m-1)\ldots(k_m-i+1) \right\rangle_{\mathrm{ev}}}{\langle N \rangle_{\mathrm{ev}}^i} \, \frac{\left(N^{\mathrm{INC}}\right)^i}{\sum\limits_{m=1}^{M} \left(k_m^{\mathrm{INC}}\right)^i} \,, \qquad (1)$$

* Presented at the XXVII Mazurian Lakes School of Physics, Krzyże, Poland, September 2–9, 2001.

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

The $\langle F_i^{\delta X}\rangle$ moments calculated for different widths of δX have interesting properties: in the limit of infinite multiplicity for Poissonian fluctuations of bin occupancies in X distribution values of the $\langle F_i^{\delta X}\rangle$ are close to 1, but for Poissonian and in addition dynamical fluctuations values of the $\langle F_i^{\delta X}\rangle$ are greater then 1.

Intermittency implies a characteristic power-law dependence of the normalised scaled factorial moments on the bin size:

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

The exponent α_i is called the "intermittency exponent". When intermittency occurs, the moments reflect the self-similarity at various resolutions.

It is known that mixing of events corresponding to different impact parameters may produce a trivial intermittent behaviour [4], therefore, it is very important to set stringent centrality selection criteria. Two selection criteria were used: high multiplicity (PM5) and high transversal-to-longitudinal energy ratio (ERAT5) [5]. Parameter values of the selection criteria for all analysed energies were taken from Ref. [6]. Events for which simultaneously both centrality criteria were fulfilled were used in the analysis.

In the following results of our analysis of the Au+Au collisions at 150, 250, 400, 600 and 800 AMeV beam energy are presented. The data were obtained with the FOPI detector [7] at the SIS accelerator in GSI Darmstadt. The horizontal normalised scaled factorial moments were calculated for charge, rapidity and azimuthal angle distributions in an event-by-event analysis. For the analysis in rapidity and azimuthal angle we chose only fragments with charge equal to 1. Distinct intermittency occurred only in azimuthal angle for all analysed energies.

In order to determine the possible contribution due to apparatus effects and centrality mixing the use of model predictions is required. Two event generators were used: the statistical code WIX [8] and the Isospin Quantum Molecular Dynamics code (IQMD) [9, 10]. The statistical model provides a good reference, because it does not produce any dynamical fluctuations. A sample of events corresponding to impact parameters b varying from 0 to 3 fm was generated. The collision process was reduced to one source emission with the number of participants (source size) depending on the impact parameter. The collective expansion, and the inter-fragment Coulomb repulsion were included. The IQMD event generator [9, 10] was

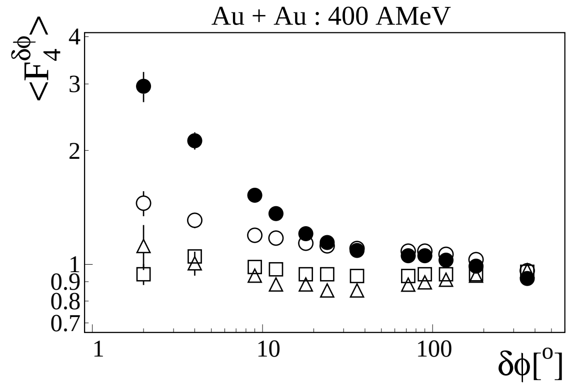

Fig. 1. Values of $\langle F_4^{\delta\phi} \rangle$ calculated for the azimuthal angle distribution, as a function of bin widths $\delta\phi$, for four samples of events: the experimental data (full circles), generated by WIX (triangles), generated by IQMD: "fixed IQMD" (squares) and "rotated IQMD" (open circles).

used to simulate central ($b < 3$ fm) collisions. Calculations were performed for the hard equation of state with momentum dependent and Coulomb interactions. The coalescence procedure [11] was applied.

In order to compare experimental results with model calculations, the response function of the FOPI detector has to be taken into account. One can expect that the main apparatus effect influencing intermittency comes from multicounting of particles in neighbouring detectors. To assess the detector influence on a intermittency analysis a GEANT simulation package [12] was used. The Coulomb and hadronic interactions of registered particles with the apparatus were included.

Events, generated by both WIX and IQMD, were used as input to the GEANT code. The IQMD events were analysed in two ways: with the reaction plane fixed in the detector coordinates (from now on called "fixed IQMD"), and when the reaction plane was randomly rotated (called "rotated IQMD"). After the GEANT simulation the horizontal normalised scaled factorial moments of rank 2 to 5 were calculated.

In Fig. 1 values of $\langle F_4^{\delta\phi} \rangle$ as a function of bin widths are presented for Au+Au at 400 AMeV. Full circles represent experimental data, triangles events generated by WIX, squares "fixed IQMD" events and open circles "rotated IQMD" events. As expected, values of the $\langle F_4^{\delta\phi} \rangle$ moments for the statistical model are around 1 and do not reproduce the experimental data. In the experiment, the reaction plane is not fixed in relation to the detector, therefore, it is appropriate to compare those results with the "rotated IQMD". As seen in Fig. 1, the "rotated IQMD" reproduces the experimental data reasonably well for $\delta\phi > 45°$. This leads us to the conclusion, that trivial non-isotropic emission patterns, rotated (together) with the reaction plane, create apparent but uninteresting from our point of view non-statistical fluctuations in the region of large $\delta\phi$.

In the small $\delta\phi$ region ($\delta\phi < 45°$) the characteristic power-law dependence, suggesting intermittency, occures. This behaviour of $\langle F_4^{\delta X} \rangle$ for $\delta\phi < 45°$ cannot be currently explained by the models of statistical (WIX) or semi-classical (IQMD) type and only partly can it be attributed to the influence of the apparatus.

In Fig. 2 values of $\langle F_i^{\delta X} \rangle$ of rank $i = 2, \ldots 5$, for central Au+Au collisions at 150, 250, 400, 600, 800 AMeV beam energy are presented. This figure contains 19 pictures. Columns represent results for different energies (energy is increasing from left to right), rows different ranks of the moments (rank is increasing from top to bottom). Only experimental data (full circles) and "rotated IQMD" (open circles) are included to make picture readable. The characteristic features of the distribution and its comparison with model calculations, seen in Fig. 1 are present at all energies and for all ranks of moments. In addition a continuous decrease of the intermittency exponent

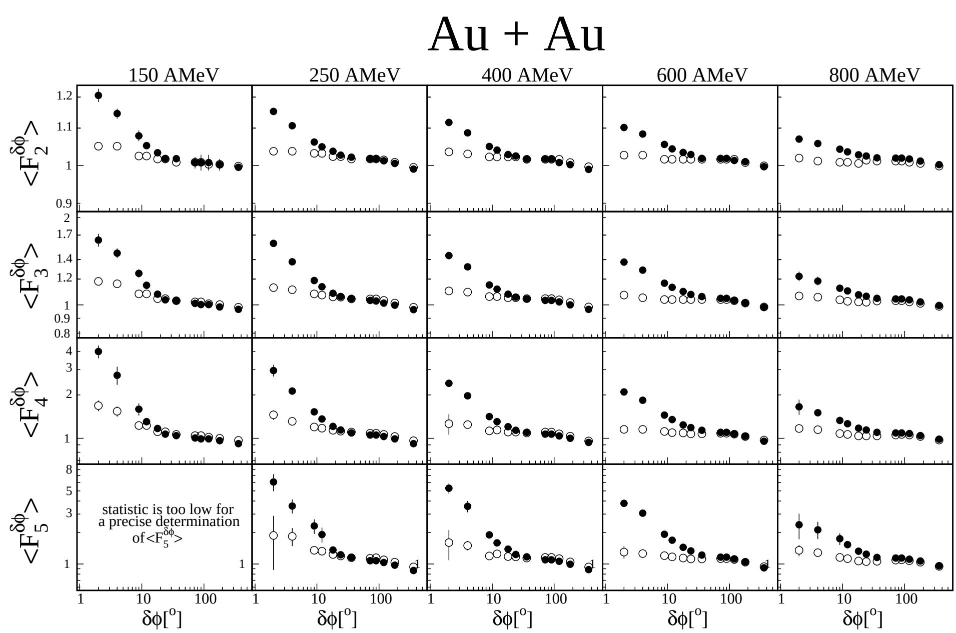

Fig. 2. Values of $\langle F_i^{\delta\phi} \rangle$ of rank $i = 2, \ldots 5$ (top to bottom), calculated for the azimuthal angle distribution, as a function of bin widths $\delta\phi$, for Au+Au collisions at five beam energies: $150, 250, 400, 600$ and 800 AMeV. Full circles represent experimental results, open circles IQMD model calculations with randomised reaction plane.

with the increase of bombarding energy can be observed. This effect as well as the regular differences between experiment and the predictions of the IQMD model (of its mostly used type) are a subject of the ongoing studies.

REFERENCES

[1] K. Wiśniewski *et al.*, *Acta Phys. Pol.* **B27**, 505 (1996).

[2] M.M. Smolarkiewicz *et al.*, *Acta Phys. Pol.* **B31**, 385 (2000).

[3] A. Białas, R. Peschansky *Nucl. Phys.* **B273**, 703 (1986); A. Białas, R. Peschansky *Nucl. Phys.* **B308**, 857 (1988).

[4] P. Bożek, M. Płoszajczak, R. Botet, *Phys. Rep.* **252**, 103 (1995).

[5] A. Gobbi *et al.*, *Nucl. Instrum. Methods Phys. Res.* **A324**, 156 (1993).

[6] U. Sodan, PHD Thesis, Heidelberg Univ., 1994.

[7] N. Herrmann, *Nucl. Phys.* **A553**, 739c (1993).

[8] G. Fai, J. Randrup, *Phys. Comm.* **42**, 3 85 (1986).

[9] J. Aichelin *et al.*, *Phys. Rev. Lett.* **58**, 1926 (1987).

[10] C. Hartnack *et al.*, *Nucl. Phys.* **A495**, 303 (1989).

[11] M. Kirejczyk, NPD Annual Rep. 2000, p. 49.

[12] GEANT CERN Program Library Long Writeup W5013.