Study of Ring-Like structures in particle emission in relativistic nuclear interactions

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INTRODUCTION

An important aim of nucleus collisions investigation at high energies is to search for a phenomena connecting with large densities obtained in such collisions. As an example, the transition from the QGP (quark - gluon plasma) back to the normal hadronic phase is predicted to contribute to fluctuations in the number of produced particles in local regions of phase space [1][2].

The goal of our work was to study the ***ring-like*** structures of produced particles in azimuthal plane. They occur if many particles are produced in a narrow region along the rapidity axis, which at the same time are almost regularly distributed over the whole azimuth (Fig.1b, Fig.2). The *jet-like* structures consist of cases, where particles are focused in both dimensions (Fig.1a).

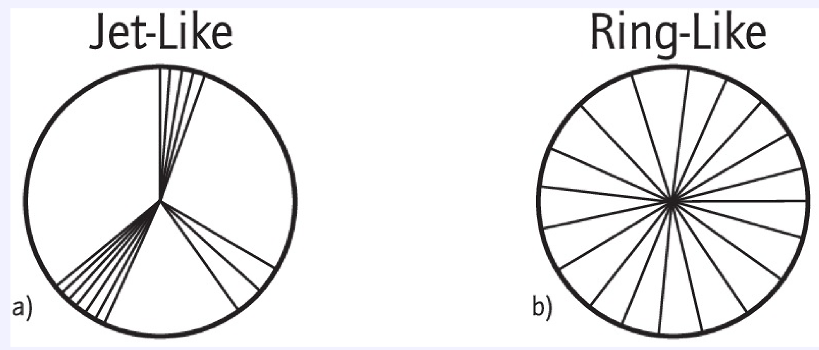

Fig. 1: Schema of the jet-like and ring-like structures in azimuthal plane. Primary track is perpendicular to figure plane.

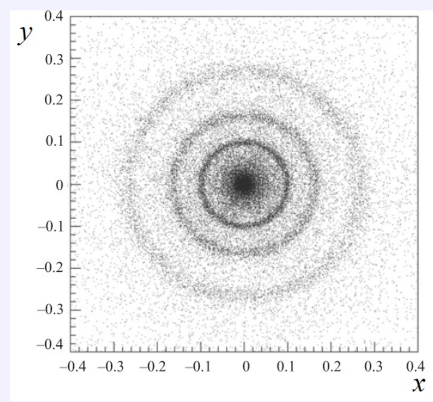

Fig. 2: Simulation of ring-like structure of particle emission.

EXPERIMENT

The stacks of NIKFI BR-2 nuclear photoemulsions have been irradiated horizontally by ^{208}Pb beam at 158 $AGeV/c$ (the CERN SPS experiment EMU12) and by ^{197}Au beam at 11.6 $AGeV/c$ (the BNL AGS experiment E863). The used photoemulsion method allows to measure: *multiplicities of any charged particles*, which include ***relativistic*** (N_s) ***particles*** with $\beta > 0.7$, projectile fragments (N_F) with $\beta \approx 0.99$ and target fragments (N_h) with $\beta < 0.7$; *angles of particles* with the resolution of $0.010 - 0.015$ rapidity units in the central region, pseudorapidity is given by $\eta = -ln(tan(\vartheta/2))$, where ϑ is the emission angle with respect to the beam direction, *charges of projectile fragments* (Z_F).

We analysed 628 $^{208}Pb + Ag(Br)$ interactions divided into three centrality groups by the number of relativistic particles ($350 \leq N_s < 700,\ 700 \leq N_s < 1000,\ N_s \geq 1000$), and 1128 $^{197}Au + Ag(Br)$ collisions also in three centrality groups ($100 \leq N_s < 200,\ 200 \leq N_s < 300,\ N_s \geq 300$).

METHOD

A method we use to search for a ring-like structure was proposed in [3]. The multiplicity N_d of analyzed subgroup of relativistic particles from an individual event is fixed. Each consecutive N_d tuple of particles along the η axis of individual event is characterized by a size $\Delta\eta = \eta_{max} - \eta_{min}$, where η_{min} and η_{max} are the pseudorapidities of the first and last particles in the subgroup and a density $\rho_d = N_d/\Delta\eta$.

To parameterize the azimuthal structure of the subgroup in a suitable way a parameter

$$S_2 = \sum(\Delta\Phi_i)^2$$

has been suggested, where $\Delta\Phi$ is the difference between azimuthal angels of two neighboring particles in the investigated subgroup. For the sake of simplicity it was counted $\Delta\Phi$ in units of full revolutions $\sum(\Delta\Phi_i) = 1$.

The parameter S_2 is large ($S_2 \to 1$) for the jet-like, small ($S_2 \to 1/N_d$) for the ring-like structures and the expected value for the stochastic scenario with independent particles can be expressed as $\langle S_2 \rangle = 2/(N_d + 1)$. Expected normalized $S_2/\langle S_2 \rangle$ distributions for different scenarios are schematically illustrated in Fig.3, using Gauss distributions.

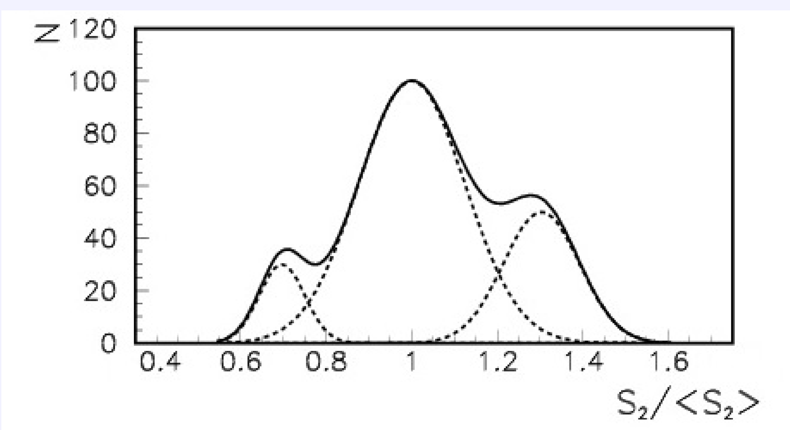

Fig. 3: The schematical normalized $S_2/\langle S_2 \rangle$ summary distribution from three effects (from the left to the right): ring-like, stochastic and jet-like effects distributions.

RESULTS

Using the presented method, we obtained for central $Au + Ag(Br)$ interactions at 11.6 $AGeV/c$ normalized $S_2/\langle S_2 \rangle$ distribution (with additional criteria $\Delta\eta < 0.3$). In Fig.4 it is fitted by three Gaussians. One can see a good agreement of experimental distribution and three Gaussians fit. Also the additional structure in the region on the left of the peak, where the ring-like substructures could give their contribution, is visible.

The experimental normalized $S_2/\langle S_2 \rangle$ distributions compared with the calculated ones by the FRITIOF model for the most central groups of events measured in ^{208}Pb and ^{197}Au induced collisions with $Ag(Br)$ nuclei at 158 and 11.6 $AGeV/c$ are presented in Fig.5. The model distributions were aligned according to the position of the peak with the experimental one. Neither ring-like nor jet-like effects are part of the FRITIOF model, so model distributions are used as a statistical background. Both experimental distributions are shifted to the right, have a tail in the right part and are broader than the FRITIOF spectra. The left parts of both experimental distributions are not as smooth as in the model and there are some shoulders that refer to the surplus of the events in this region. The results obtained from the experimental data after the subtraction of the statistical background are also shown. The resultant distributions have two very good distinguishable hills: the first, in the region $S_2/\langle S_2 \rangle < 1$, where the ring-like effects are expected and the second in the jet-like region $S_2/\langle S_2 \rangle > 1$. The probability of the formation of the nonstatistical ring-like substructures can be estimated as a rate of the surface of the ring-like part to the full surface of the experimental distribution.

The estimated contribution of the ring-like effect to the experimental data as a function of N_d for $Pb + Ag(Br)$ interactions and for the three centrality regions is presented in Fig.6. These dependencies have several maxima situated nearly the same value of N_d. In the group with $N_s \geq 1000$ dependence slowly increases, while in the two other groups the dependences are decreasing.

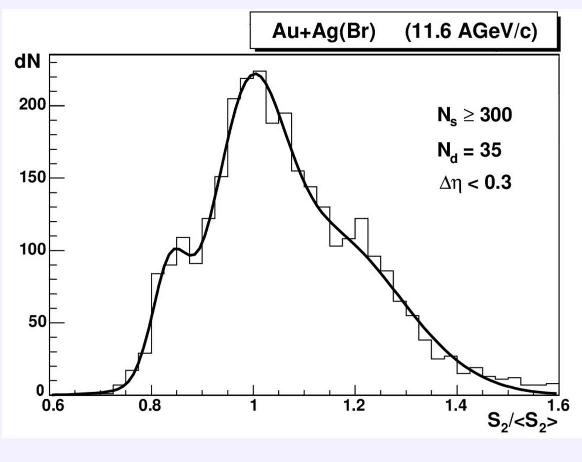

Fig. 4: The normalised $S_2/\langle S_2 \rangle$ distribution for central $^{197}Au + Ag(Br)$ collisions fitted by three Gaussians.

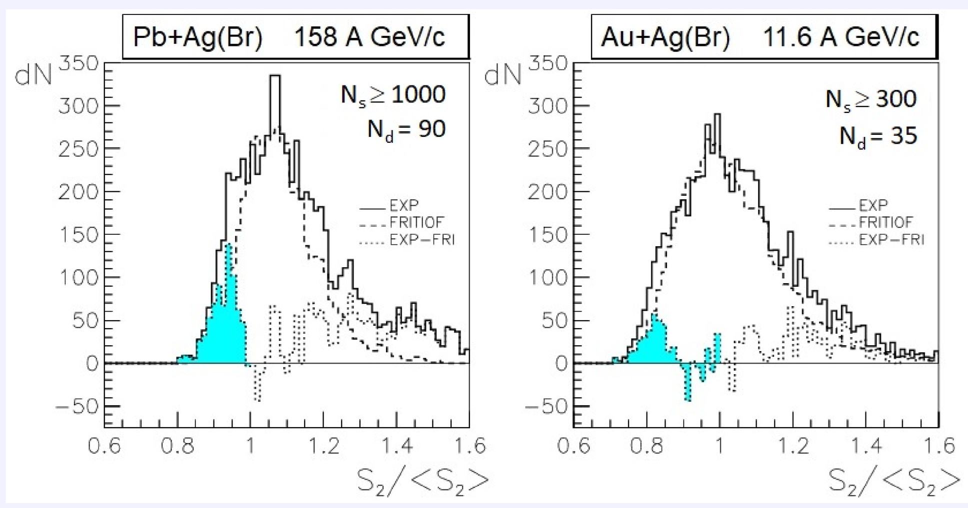

Fig. 5: The experimental and FRITIOF model normalized $S_2/\langle S_2 \rangle$ distributions for central ^{208}Pb and ^{197}Au induced collisions.

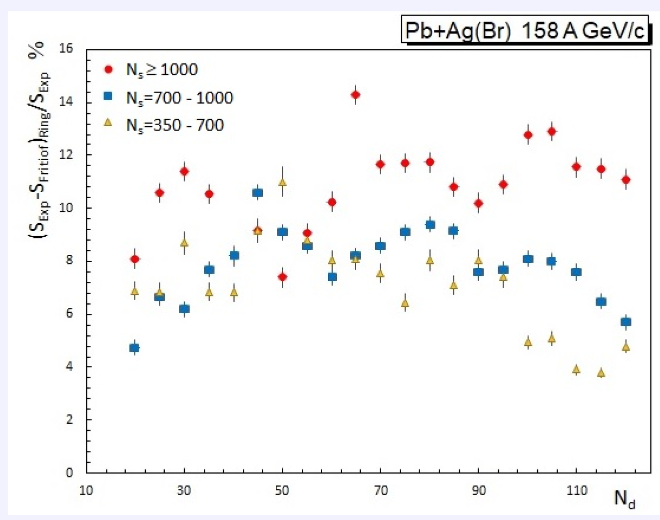

Fig. 6: The probability of ring-like structures as a function of N_d for different centralities.

CONCLUSIONS

The azimuthal ring-like substructures of produced particles from collisions of 11.6 $AGeV/c$ ^{197}Au and 158 $AGeV/c$ ^{208}Pb beams with $Ag(Br)$ targets in the emulsion detector have been investigated.

The additional subgroups of produced particles in the region of the ring-like substructures ($S_2/\langle S_2 \rangle < 1$) in comparison to the FRITIOF model calculations have been observed.

The probability of the formation of a non-statistical ring-like substructures increases with increasing multiplicity of produced relativistic particles in interaction, which takes place for more central collisions and for larger primary energies and masses. Our preliminary results for $^{208}Pb + Ag(Br)$ collisions at 158 $AGeV/c$ shown that the estimated contribution of the events with ring-like substructures is about 10-12 % in the most central group of collisions with $N_s \geq 1000$. This value slowly decreases in two other groups of less central events with $N_s = 350 - 700$ and $N_s = 700 - 1000$.

References

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ACKNOWLEDGMENT

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