Evidence of dynamical fluctuation of emission of pions produced in ultra-relativistic nuclear collisions at 200A GeV/c for different projectiles

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Relativistic heavy-ion collisions offer us to study the excited state of matter in the laboratory under extreme energy, reachable otherwise only in the hot early universe or in certain astrophysical situations of strong gravitational collapse. We know very little about the properties of nuclear matter at high densities. Relativistic nuclear collision offer us the only means at present to probe the high density and temperature domain in the laboratory. Through relativistic heavy-ion collisions we want to reach a very high temperature over extended domains many times larger than the size of the single hadron. When two nuclei collide themselves with a relativistic high energy, they generally create a colour deconfined Quark-Gluon Plasma(QGP) like state of matter. Fluctuation studies in the distributions of produced particles encapsulate rich information about the dynamics of the emitting source in the late stage of a nucleus-nucleus collision where the nuclear matter is highly excited and diffused. One of the signatures of QGP formation are the larger non-statistical fluctuation among pions produced. In this paper we have studied the dynamical fluctuation in the azimuthal angle distribution of the pions produced in ^{16}O-Ag/Br and ^{32}S-Ag/Br interactions at an incident momentum of 200A GeV/c. To find asymmetry in distribution of produced pions, the data sets used in the present analysis were obtained by irradiating Ilford-G5 emulsion stacks by ^{16}O and ^{32}S beam incident energy 200 A GeV/nucleon at CERN,SPS[1-2].

We divide the whole azimuthal plane having 2π angular range into two equal angular intervals and the difference in the number of shower track emitted in the two intervals for each of the events is found out. We repeat the process and continue it by shifting the line of division over the azimuthal plane by 10^0 and by taking the difference in the number of shower tracks in the two halves. This process is carried out till the position of the line of division is repeated. The maximum difference obtained for each event is taken as Δn_{si} (i indices the event) . The probability of azimuthal asymmetry for the ith event is defined[3] as $W_i = \frac{\Delta n_{si}}{n_{si}}$ .Where n_{si} is the total number of shower tracks in the ith event of the group of events in a particular N_s interval. For a group of m events in an N_s interval, the probability of azimuthal asymmetry is then given as $\overline{W} = \sum_i \frac{W_i}{m}$. To calculate the symmetry parameter ($\overline{W}$) the data sample is divided into such groups that all the events in a particular group have almost equal number of shower tracks. Then we calculate the $\overline{W}$ for different $\overline{N_s}$ intervals for the two kind of data set. For any particular N_s interval the weighed average of N_s is given by $\overline{N_s} = \sum P_{N_s} N_s$. Where P_{N_s} represents the probability of obtaining an event with N_s number of shower tracks.

To study the variation of azimuthal asymmetry with the number of shower tracks, the calculated of probability $\overline{W}$ of azimuthal asymmetry and their corresponding weighed averages $\overline{N_s}$ for the two kind of data set are given in table 1.

Table.1*:The values of the probability* $\overline{W}$ *of azimuthal asymmetry in different* $\overline{N_s}$ *intervals for* ^{16}*O-Ag/Br and* ^{32}*S- Ag/Br interactions at 200 A GeV*

Interactions	$\overline{N_s}$	$\overline{W}$	
		Exper-iment	**Monte-Carlo**
^{32}S-Ag/Br interaction at 200A GeV/C	095.470	0.307	0.248
	148.111	0.226	0.193
	194.122	0.218	0.174
	260.846	0.197	0.131
	319.128	0.145	0.119
	369.818	0.105	0.104
^{16}O-Ag/Br interaction at 200A GeV/C	034.020	0.430	0.335
	064.570	0.327	0.254
	087.000	0.312	0.248
	113.500	0.282	0.221
	138.580	0.252	0.178
	172.230	0.187	0.155
	212.600	0.182	0.142

In fig.(1,2) we have plotted $\overline{W}$ against $\overline{N_s}$ with the experimental data sets of ^{16}O-Ag/Br and ^{32}S- Ag/Br interactions at 200A GeV/c. The figures for both the data sets reveal that $\overline{W}$ for shower tracks depends on the $\overline{N_s}$ interval. $\overline{W}$ decreases with the increase of $\overline{N_s}$ indicating that asymmetry decreases with the number of shower tracks.

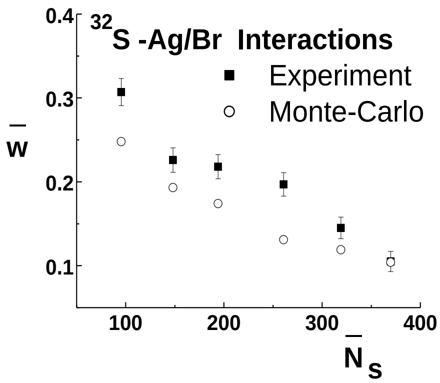

Fig.1

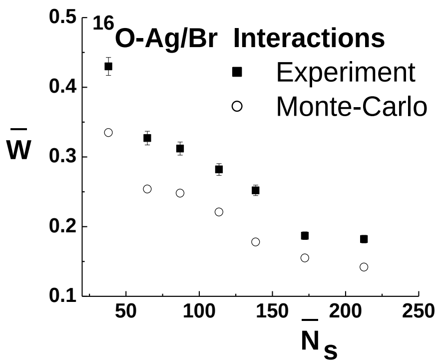

Fig.2

Fig.1 & Fig.2: *Plot of the probability $\overline{W}$ of azimuthal asymmetry against $\overline{N_s}$ for both experimental and simulated data for ^{32}S- Ag/Br and ^{16}O-Ag/Br interactions at 200A GeV respectively.*

To understand whether the characteristics revealed above is a mere reflection of statistics, the original data file has been randomly shuffled. The same procedure has been followed in determining the probability of azimuthal asymmetry with the randomized data set. The results for the randomized data set shows that the probability of azimuthal asymmetry for most of the points differs appreciably from that of the experimental values The $\overline{W}$ vs $\overline{N_s}$ plot reveals that the experimental data set follow a power law of the form $\overline{W} = p\overline{N}_s^q$. The values of p and q obtained from the best fit (fig3) for ^{16}O-Ag/Br and ^{32}S- Ag/Br interaction at 200A GeV. Values are tabulated in the table 2.

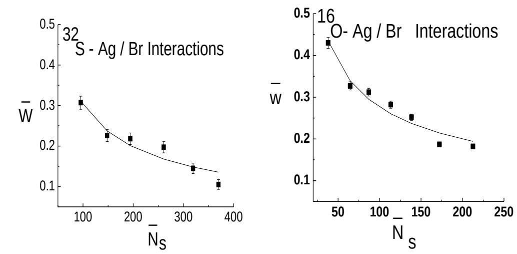

Fig.3: *power law best-fit curves for expt data sets*

We see that the values obtained by best fit are different for two cases.

Table2:*The values of p and q per degree of freedom for ^{16}O-Ag/Br and ^{32}S- Ag/Br interactions at 200A GeV*

Interactions	p	q
^{32}S-Ag/Br interactions at 200A GeV/C	5.05374	-0.61204
^{16}O-Ag/Br interactions at 200A GeV/C	2.39174	-0.46872

So the above analysis indicates that

- Pions are emitted asymmetrically in the azimuthal space.
- The degrees of asymmetry depends on the value of the pions multiplicity and they decrease with the increase of pions multiplicity.
- The different values of p as well as q obtained by fitting $\overline{W}$ vs $\overline{N_s}$ for same energy but different projectiles(^{16}Oand ^{32}S) may suggest that the degree of azimuthal asymmetry decreases faster for the heavier projectile.

Finally we may arrive at the very interesting conclusion that the emission of pions become more and more symmetric with the increase of pions multiplicity. This behavior is a reflection of dynamics of emission process as evident from simulated data.

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