Jet-like structure and Two-dimensional intermittency study at CERN SPS Energy

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Studying or probing highly excited nuclear dense matter under controlled conditions in the laboratory has proven their worth in exploring the nature of matter in extreme conditions of temperature and density. Under such extreme conditions a new form of matter called Quark Gluon Plasma (QGP) is created **[1]**. In analyses of azimuthal distributions of produced particles two different classes of substructures were revealed, which could be referred to as jet-like and ring-like structures[2]. For ring-like structures where the particles are confined to a limited η interval and distributed more or less uniformly over the entire Φ range, the strong one dimensional(*1d*) intermittency is expected. On the other hand, for jet-like structures, where the particles are restricted over narrow regions of η and Φ both, the 2*d* intermittency should be strong. In high energy interactions a very little attention is paid to the target-evaporated slow particles in comparison to the produced pions. We have studied the ring-jet and 2d intermittency analyses for target evaporated particles for ^{16}O-Ag/Br & ^{32}S-Ag/Br interactions at 60A GeV/c & 200A GeV/c respectively [3] at CERN SPS energy. In this work we have followed the method to search for a ring-like and jet-like substructure described by Adamovich *et al* **[4]**. To parameterize the azimuthal structure, two parameters are introduced namely, $S_1 = -\sum \ln(\Delta\varphi_i)$ & $s_2 = \sum (\Delta\varphi_i)^2$.Where $\Delta\varphi_i$ is the azimuthal difference between two consecutive particles in a group. Both S_1 *and* S_2 *are* small ($S_1 \rightarrow N_d \ln(N_d)$ and $S_2 \rightarrow 1/N_d$) for ring-like structures and are large ($S_1 \rightarrow \infty$ and $S_2 \rightarrow 1$)for jet-like structures. While S_1 is sensitive to small gaps, S_2 is sensitive only to large gaps. Stochastic value of the two parameter,$< S_1 >= N_d \sum_{k=1}^{N_d-1}(\frac{1}{k})and< S_2 >= \frac{2}{N_d+1}$ .We can use Monte Carlo simulation as an independent emission model which would serve as a statistical background.

The SFM of order q is defined as

$$< \boldsymbol{F_q} >= \frac{1}{M}\sum_{m=1}^{M} \frac{<n_{em}(n_{em}-1)......(n_{em}-q+1)>}{<n_m>^q}$$

Where n_{em} is the number of target fragments falling within the mth interval of the eth event, < > denotes an averaging over the number of events and q is the order of the moment. M (=$M_\eta . M_\varphi$) is the total 2d phase space partition number and $M_\eta(M_\varphi)$ is the partition number along the η (φ) direction. If the 2d dynamical fluctuations are self similar at all scales then one expect to see a linear relation like $\ln < F_q >= \varphi_q \ln M + A_q$, where A_q is the intercept and the slope φ_q(>0) is the intermittency index and it measures the strength of the intermittency. We have performed a self-affine analysis of our multiplicity fluctuation data with a continuously diminishing scale of phase-space resolution **[5].** The phase-space scale factors in different directions are related as $M_\eta = M_\phi^H$ for 0<H < 1.0 and $M_\phi = M_\eta^{(1/H)}$ for H > 1.0. The 'H' is called the Hurst exponent.

We have chosen N_d=7 for ^{16}O-Ag/Br and ^{32}S-Ag/Br events. The corresponding expectation (stochastic) values of S_1 and S_2 are $<S_1>$=17.15 and $<S_2>$= 0.25 respectively. In fig.1 and fig.2 we have plotted $<-\sum \ln(\Delta\varphi_i)>$ vs Δη and $<\sum (\Delta\varphi_i)^2>$ vs Δη distributions for both type of interactions. We find that the distribution of the data obtained from the MC simulation lie more or less along the stochastic expectation line indicated by the solid line, in both the cases. Experimental data points for ^{16}O-Ag/Br interaction (fig.1 (a), fig.2 (a)) are more or less along the stochastic average line. But for ^{32}S-Ag/Br interaction (fig.1(b), fig.2(b)), the experimental data points have a slight tendency to be above the stochastic expectation line for both the distributions. So from the average behavior of S_1 & S_2, we can conclude the faintly presence of jet-like substructure for both the interactions.

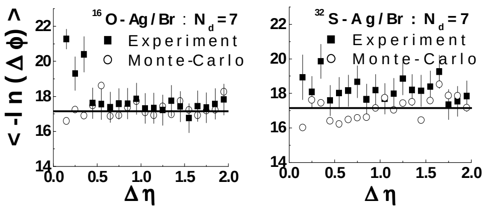

Fig.1 (a) **Fig.1 (b)**

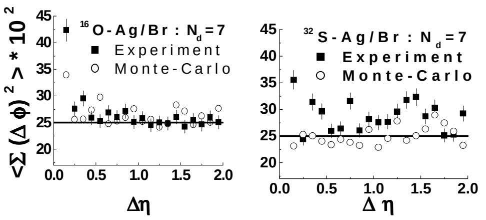

Fig.2 (a) **Fig.2 (b)**

Setting $M_\eta = M_\varphi$, we have plotted 2d SFM for different order in fig.3 for both type of interactions. The variation of $\ln\langle F_q\rangle$ with lnM is

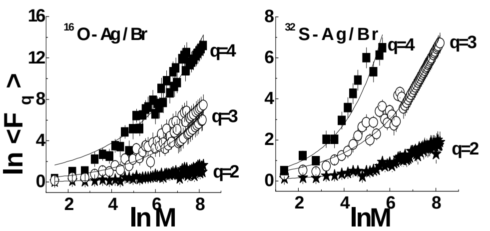

Fig. 3 (a) **Fig. 3(b)**

Table-1

Order	^{16}O-Ag/Br		^{32}S-Ag/Br	
	Φ_q	R^2	Φ_q	R^2
q=2	0.117±0.031	0.850	0.163±0.034	0.887
q=3	0.741± 0.088	0.922	0.761±0.085	0.927
q=4	1.787±0.133	0.961	1.648±0.187	0.962

not linear in full lnM region. To obtain a measure of the self-affine intermittency index in 2d, one can perform a polynomial fit for data sets and can then retain the linear coefficient by setting all nonlinear coefficients to zero. The results of 2d intermittency index are presented in table-1, for both the interactions. The self-affine analysis for q=2 has been performed for a wide range of H values for both type of interaction. Nonlinear variation in each case is fitted with a quadratic function like $y=ax^2+bx+c$. The values of 'a', 'b' and r^2 are tabulated for various H in table-2 for ^{16}O-Ag/Br interaction and ^{32}S-Ag/Br interaction in table-3.

From fig.4 (a) we can find that $\ln\langle F_2\rangle$ varies

Table-2

H	^{16}O-Ag/Br interaction at 60A GeV/c		
	a	b	R^2
0.30	0.012±0.006	0.039±0.045	0.996
0.35	0.013±0.006	0.023±0.044	0.996
0.80	0.026±0.009	-0.080±0.070	0.995
1.0	0.035±0.009	-0.159±0.099	0.996
3.0	0.01298±0.005	0.006±0.032	0.994
4.0	0.002±0.005	0.064±0.034	0.996

Table-3

H	^{32}S-Ag/Br interaction at 200A GeV/c		
	a	b	R^2
0.30	0.047±0.008	-0.163±0.055	0.996
0.35	0.03649±0.007	-0.101±0.051	0.996
0.80	0.049±0.009	-0.205±0.075	0.995
1.0	0.047±0.006	-0.187±0.061	0.996
3.0	0.05805±0.005	-0.222±0.037	0.994
4.0	0.043± 0.006	-0.154±0.038	0.996

linearly with lnM for H=0.3 for ^{16}O-Ag/Br

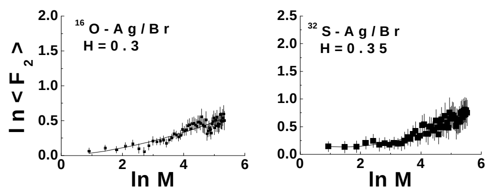

Fig.4 (a) **Frig.4 (b)**

interactions. So self similarity is obtained for ^{16}O-Ag/Br interaction at H=0.3. For ^{32}S-Ag/Br interaction the self similarity is obtained at H=0.35 which is also shown in fig.4 (b).

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