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Cosmic and Subatomic Physics
University of Lund
Sölvegatan 14
S-223 62 Lund, Sweden

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E Stenlund[7], M I Adamovich[10], M M Aggarwal[3], R Arora[3], Y A Alexandrov[10], S A Azimov[14], S K Badyal[6], E Basova[13], K B Bhalla[5], A Bhasin[6], V S Bhatia[3], R A Bondarenko[13], T H Burnett[12], X Cai[15], L P Chernova[14], M M Chernyavski[10], B Dressel[9], E M Friedlander[2], S I Gadzhieva[14], E R Ganssauge[9], S Garpman[7], S G Gerassimov[10], A Gill[5], J Grote[12], K G Gulamov[14], U G Gulyamov[13], V K Gupta[6], S Hackel[9], H H Heckman[2], B Jakobsson[7], B Judek[11], F G Kadyrov[14], H Kallies[9], L Karlsson[7], M Kaur[3], S P Kharlamov[10], S Kitroo[6], J Kohli[6], G L Koul[6], V Kumar[5], P Lal[5], V G Larionova[10], P J Lindstrom[2], L S Liu[15], S Lokanathan[5], J Lord[12], N S Lukicheva[14], L K Mangotra[6], N V Maslennikova[10], I S Mittra[3], E Monnand[4], S Mookerjee[5], C Mueller[9], S H Nasyrov[13], V S Navotny[14], G I Orlova[10], I Otterlund[7], N G Peresadko[10], S Persson[7], N V Petrov[13], W Y Qian[15], R Raniwala[5], S Raniwala[5], N K Rao[6], J T Rhee[9], N Shaidkhanov[13], N G Salmanova[10], W Shultz[9], F Schussler[4], V S Shukla[5], D Skelding[12], K Söderström[7], R S Storey[11], J F Sun[8], L N Svechnikova[14], M I Tretyakova[10], T P Trofimova[13], H Q Wang[15], Z O Weng[8], R J Wilkes[12], G F Xu[1], P Y Zheng[1], D C Zhou[15] and J C Zhou[15]

1) Beijing, Academica Sinica, Peoples Republic of China
2) Berkeley, Lawrence Berkeley Lab, USA
3) Chandigarh, Panjab University, India
4) Grenoble, C.E.N.
5) Jaipur, University of Rajasthan
6) Jammu, University of Jammu, India
7) Lund, University of Lund, Sweden
8) Linfen, Shanxi Normal University, Peoples Republic of China
9) Marburg, Phillips University, West Germany
10) Moscow, Lebedev Institute, USSR
11) Ottawa, NRC, Canada
12) Seattle, Washington University, USA
13) Tashkent, Inst. Nucl. Phys., USSR
14) Tashkent, Physical-Technical Inst., USSR
15) Wuhan, Hua-Zhong Normal University, Peoples Republic of China

Fluctuations in particle densities of non-statistical origin are studied in central ^{16}O+Ag(Br) and ^{32}S+Au interactions at 200 A GeV. Non-statistical fluctuations in the ^{32}S-induced interactions seem to enhance the local particle densities, and suggest the presence of intermittency. The fluctuations are found to be accompanied by a clustering tendency also in the azimuthal plane. A new method for the study of azimuthal correlations is proposed.

(Talk given at QM'88, Lennox, Massachusetts, Sept 25-30, 1988)

One of the proposed signals for collective phenomena in relativistic heavy ion interactions is large fluctuations in the number of produced particles in local regions of phase space. As an example, the transition from the QGP back to the normal hadronic phase, is predicted to give rise to such fluctuations[1].

The EMU01-experiment was specially designed to be able to measure angles of produced charged particles with extremely high accuracy[2]. For that purpose a technique with vertically exposed emulsion chambers, consisting of several emulsion layers, were used and a semiautomatical measurement system to facilitate the measurements was devised. With this technique it was possible to keep the errors in the pseudorapidity, $\eta = -\ln \tan \theta/2$, for a particle produced in the region $1 < \eta < 7$ smaller than 0.013 units of pseudorapidity. The emulsion chambers were exposed to the CERN oxygen beam at 200 A GeV in 1986, and in 1987 chambers equipped with thin gold-foils were exposed to the sulphur beam. The high accuracy makes this experiment well suited for studies of non-statistical fluctuations of particles along the η-axis down to regions, $\Delta\eta$, of 0.01 units of pseudorapidity. Some results from the ^{16}O-run have been published elsewhere[3].

For this study 80 ^{16}O+Ag(Br) events with more than 150 charged particles within a 30° ($\eta \simeq 1.3$) cone and 40 preliminary ^{32}S+Au events with a corresponding multiplicity cut at 300 charged particles were selected. The cuts correspond to 15 - 18% of the estimated minimum bias cross section. The multiplicity cut for the ^{16}O-induced interactions automatically excludes the contribution from the lighter target components (H, C, N and O) in the emulsion, verified by FRITIOF-calculations. The events were analyzed using normalized factorial moments,

$$F_k(\Delta\eta) = M^k < \prod_{i=1}^{k} (n-i+1) > / \prod_{i=1}^{k} (N-i+1) , \qquad (1)$$

where N is the event multiplicity, M the number of $\Delta\eta$-bins and n is the multiplicity inside a bin of size $\Delta\eta$, as proposed by Bialas and Peschanski[4]. The approach has the advantage that the moments will be independent of $\Delta\eta$ whenever $\Delta\eta$ is less than the typical size related to the fluctuations. Furthermore, intermittancy shows up as a power-law behaviour on $\Delta\eta$.

Besides the two experimental data samples, two event samples generated by the Monte-Carlo code FRITIOF[5], were used for comparisons. In the analyzis the same conditions were applied to the FRITIOF-samples as to the experimental ones. The fraction of the cross section remaining after the multiplicity cut is approximately the same as for the experimental data, i e 17% for the ^{16}O-induced and 19% for the ^{32}S-induced interactions, respectively.

In fig 1, the normalized second factorial moments, F_2, of the multiplicity distributions as a function of bin width in pseudorapidity, are shown. The solid curves are from the FRITIOF model, and the deviations from the model and zero correlations, mainly depend on the change of the average particle density inside the studied pseudorapidity window. Similar results are obtained for higher orders, k. When plots like these are studied, it is important to realize that all points (one for each chosen bin-size) contain essentially the same information, i e points nearby along the abscissa are strongly correlated. The same is also true between moments of different orders, k. With this in mind it is impossible to claim that the oxygen data shows a significant deviation from the model. The sulphur data, however, seems to deviate from the model, with a rise in the moments down to very small values of $\Delta\eta$, indicating that sources of many different sizes are at play, i e intermittancy.

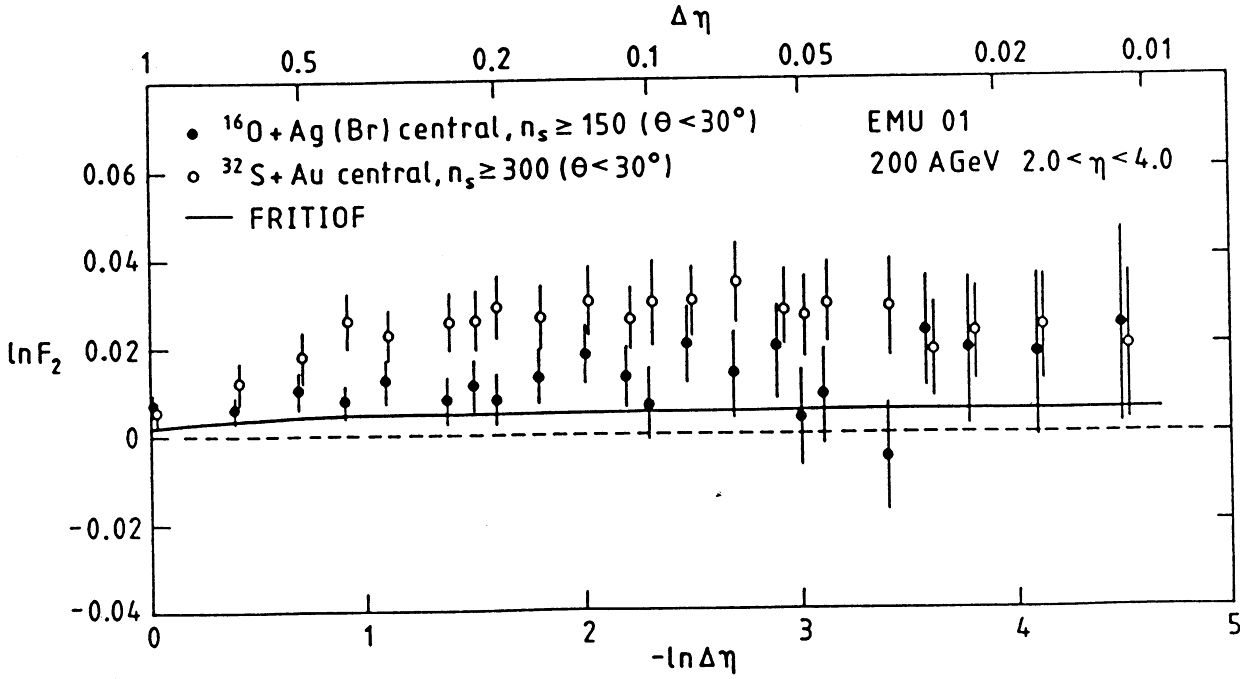

FIGURE 1

The normalized factorial moments F_k of the multiplicity distribution as a function of bin width in pseudorapidity for k = 2 for the region $2.0 < \eta < 4.0$.

The question that now arises is "If there are any non-statistical fluctuations in the longitudinal direction, will they, in that case, be accompanied by corresponding fluctuations in the transverse direction ?". If, for instance, some source like a fireball of some kind is responsible for the fluctuations, a small transverse motion of this source should be detectable. Also a directed emission from a QGP could give rise to longitudinal as well as transversal fluctuations. In central collisions effects like shock wawes etc. could tend to smear out the particles in the azimuthal plane. Such a question can only be answered if the events are measured with a detector having a perfect ϕ-symmetry and a close to 100% efficiency. Again, the idea with emulsion chambers together with the measurement system, seems ideal.

In an attempt to answer the question each event is scanned for the narrowest pseudorapidity window containing exactly n_Δ observed particles, which in the following is referred to as a cluster. In the so found clusters the particles are ordered in azimuthal angle, and the $\Delta\phi$ between each consecutive pair of particles are recorded. The angles are normalized so that the full revolution equals unity, i e $\Sigma(\Delta\phi) = 1$. For each cluster the azimuthal-correlation parameters $\sqrt{\Sigma(\Delta\phi)^2}$ and $-\Sigma\ln(\Delta\phi)$ are calculated. Both of these parameters are smallest whenever the particles are produced equidistant and increases as the particles are clustering in the azimuthal plane. The parameter $\sqrt{\Sigma(\Delta\phi)^2}$ is mainly sensitive to the large gaps, $\Delta\phi$, in the cluster, whereas $-\Sigma\ln(\Delta\phi)$ is mainly sensitive to the smaller ones. Thus the two parameters may contain complementary information.

In figure 2, not only the narrowest clusters from each event, but instead all possible combinations of n_Δ consecutive particles, are extracted. For $n_\Delta > 2$ this means that closelying clusters are strongly correlated due to the overlap. This effect is, however, taken into account in the calculation of the statistical errors. The average correlation parameter $-\Sigma\ln(\Delta\phi)$, as defined above, are shown as a function of the width of the clusters. Particles emitted at $\eta > 6$, are excluded here, since a small misalignement of the individual event will tend to rise the values of the correlation parameters above the statistical level. For particles with $\eta < 6$, this effect certainly becomes negligable. Again the dashed levels indicate the average values for random emission, in all cases coinciding with the results from FRITIOF. The oxygen-sample show no dependence on $\Delta\eta$, for any values of n_Δ, but again the sulphur-sample shows a deviation from the expectation with a clustering effect for small values of $\Delta\eta$. One might argue that the way of selecting clusters may distort the effect since a possible "non-

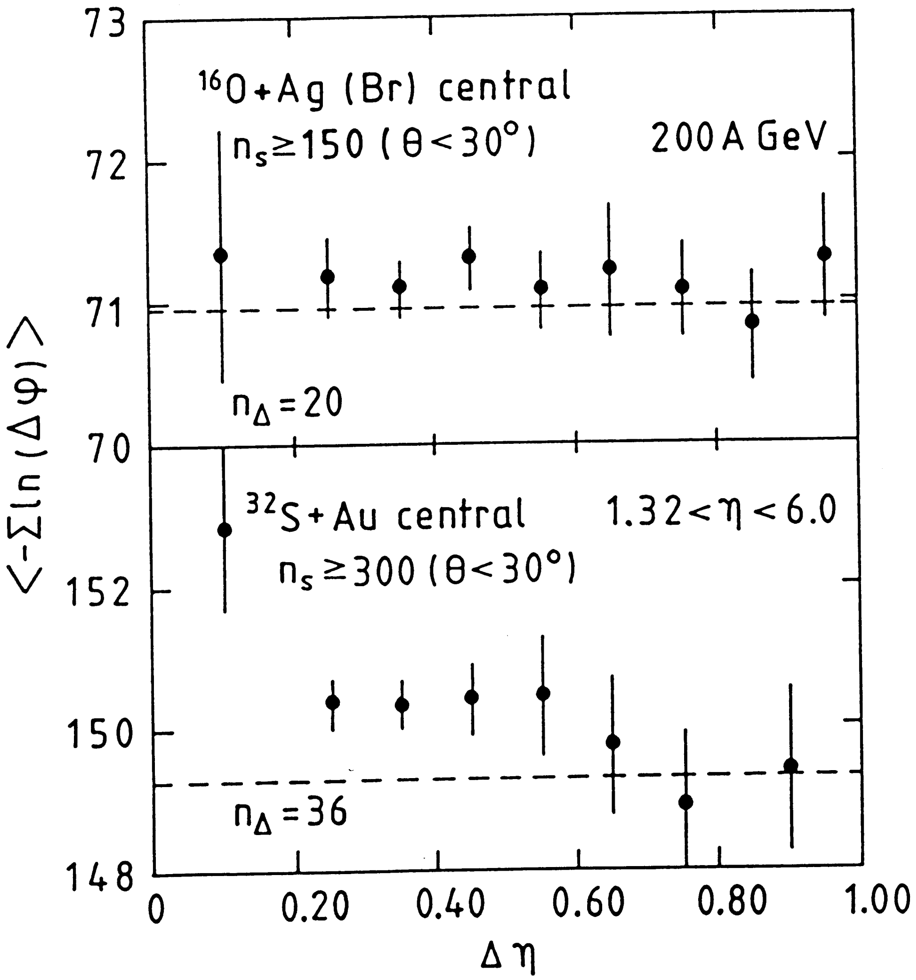

FIGURE 2

The azimuthal correlation parameter $-\Sigma\ln(\Delta\phi)$ averaged over the selected "clusters" as a function of $\Delta\eta$.

statistical fluctuation" may end up in several different clusters with different $\Delta\eta$-values. On the other hand the method can not create an effect which is not already there from the beginning. In the case of $n_\Delta = 2$ (not shown here), an effect of Bose-Einstein correlations is seen for the smallest values of $\Delta\eta$ for both data samples.

To summarize, a small effect of non-statistical fluctuations in the longitudinal direction is observed for central ^{32}S + Au interactions at 200 A GeV. Also a small effect for the largest "clusters" are seen in the transversal direction. The last effect shows a dependence on the width of the "cluster", i e clusters with large particle densities show an enhanced azimuthal clustering.

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1. L. van Hove, Z. Phys. C21(1984)93;
   M. Gyulassy et al., Nucl. Phys. B237(1984)477.
2. S. Garpman et al., Nucl. Instr. and Methods A269(1988)134.
3. M. I. Adamovich et al., Phys. Lett. B201(1988)397.
4. A. Bialas and R. Peschanski, Nucl. Phys. B273(1986)703.
5. B. Andersson, Nucl. Phys. A447(1986)165c;
   B. Andersson et al., Phys. Scripta 34(1986)451;
   B. Nilsson-Almqvist and E. Stenlund, Comput. Phys. Commun. 43(1987)373.