Split-bin correlation-function analysis of O+Ag(Br) and S+Ag(Br) collisions at 200 GeV/nucleon

David Seibert*
School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455
(Received 8 November 1990)

I present the results of a split-bin correlation-function analysis of O+Ag(Br) and S+Ag(Br) collisions at 200 GeV/nucleon. The data are corrected for the shape of the single-particle pseudorapidity distribution, and are also corrected *event by event* for multiplicity. The observed pseudorapidity correlations are an order of magnitude larger than correlations from $\bar{p}p$ and e^+e^- collisions.

Pseudorapidity correlations in high-energy nuclear collisions are 10–30 times as strong as in $\bar{p}p$ or e^+e^- collisions, when corrected for multiplicity density [1]. The best existing studies of pseudorapidity correlations have been performed using scaled factorial moments [2]. Recently, a family of superior correlation functions was proposed, the split-bin correlation functions [3], or SBCF's. In this Brief Report I present the first split-bin correlation-function analysis of pseudorapidity correlations in nuclear collisions, using data obtained from the KLM Collaboration [4].

To perform the analysis, I first divide the window from 1 to 5 units of pseudorapidity into M bins of size $\delta\eta$, and split each bin into two equal pseudorapidity sub-bins, labeled L and R. I use values of $\delta\eta$ that differ by factors of 2, so that the data points are uncorrelated [3]. I then construct the so-called exclusive SBCF

$$S_2^e(\delta\eta)=M\sum_{m=1}^{M}\left\langle\frac{n_{m,L}n_{m,R}}{N_L N_R}\right\rangle , \tag{1}$$

and its inclusive counterpart

$$S_2^i(\delta\eta)=M\sum_{m=1}^{M}\frac{\langle n_{m,L}n_{m,R}\rangle}{\langle N_L N_R\rangle} , \tag{2}$$

where $n_{m,L(R)}$ is the number of particles in the $L(R)$ sub-bin of the mth bin, and $N_{L(R)}$ is the number of particles in the $L\,(R)$ sub-bin of the entire pseudorapidity window. The results of these constructions, which are equal to within experimental error, are shown in Fig. 1. I estimate errors for all exclusive constructions from the measured event-to-event fluctuations.

As the two formulations are equal, and as S_2^e lends itself to event-by-event corrections, I use the exclusive formulation of all SBCF's for the remainder of this paper. In general, the exclusive correlation functions are usually equivalent to their inclusive counterparts [1], and they allow for better data manipulation. The inclusive correlation functions are usually easier for theorists to calculate, but it is preferable for experimental purposes to use exclusive forms.

I present S_2-1 in Fig. 1 because $S_2=1$ in the absence of correlations if the single-particle pseudorapidity distribution is flat. The single-particle distribution [5] is not flat, however, and so in Fig. 2(a) I show S_2-R, where R is the expected value of S_2 in the absence of correlations from the curved single-particle pseudo-rapidity distribution. This correction is given by [3]

$$R(\delta\eta)=M\sum_{m=1}^{M}\frac{\langle n_{m,L}\rangle\langle n_{m,R}\rangle}{\langle N_L\rangle\langle N_R\rangle} . \tag{3}$$

From Fig. 2(a), I obviously have no clear signal of correlations. None of the data points are further than about one standard deviation from the uncorrelated background. However, the multiplicity varies greatly from event to event, and this is the main source of the fluctuations that I interpret as experimental error when constructing S_2-R.

I correct for these multiplicity fluctuations by constructing $\langle(dN/d\eta)(S_2-R)\rangle$, where $dN/d\eta=N/4$ for N particles in the pseudorapidity window. The results are shown in Fig. 2(b). The signal-to-noise ratio is improved by over a factor of 2, and the errors are now just slightly larger than the estimated (statistical) sampling er-

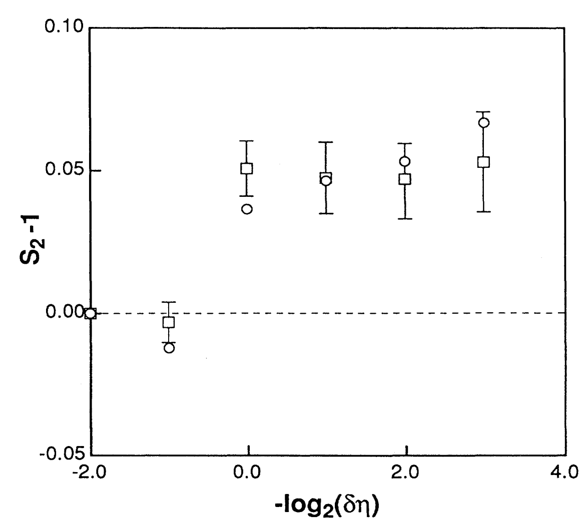

FIG. 1. S_2^e-1 (squares) and S_2^i-1 (circles) vs $-\log_2(\delta\eta)$, for 133 central O+Ag(Br) collisions at 200 GeV/nucleon. Errors are shown only for S_2^e.

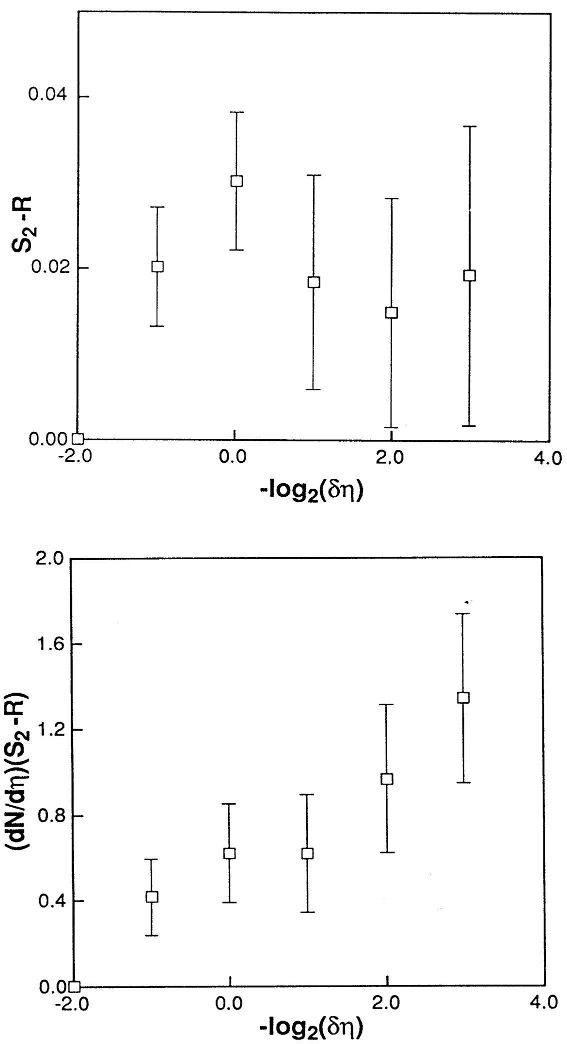

FIG. 2. O+Ag(Br) collision data before and after multiplicity corrections: (a) $\langle S_2-R\rangle$ vs $-\log_2(\delta\eta)$, 133 central events; (b) $\langle (dN/dn)(S_2-R)\rangle$ vs $-\log_2(\delta\eta)$, 92 events with at least 100 particles in the pseudorapidity window.

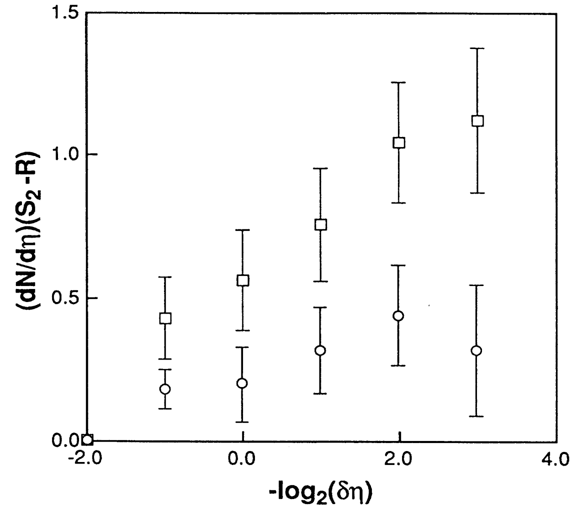

FIG. 3. O+Ag(Br) and S+Ag(Br) collision data for 231 events with at least 100 particles in the pseudorapidity window: $\langle (dN/dn)(S_2-R)\rangle$ (squares) and $\langle (dN/dn)(S_2^\phi-R)\rangle$ (circles) vs $-\log_2(\delta\eta)$.

rors. The multiplicity correction is equivalent to rescaling all correlation measurements to the value at $dN/d\eta=1$, assuming superposition of independent events, and gives the best measure of the strength of the correlations [3]. This construction is modified to $\langle (dN/d\eta)(S_2-R)\rangle/e$ for a detector with efficiency e, where all quantities are measured *without* corrections for efficiency.

The results of my analysis for the KLM O+Ag(Br) data are virtually identical to those for the KLM S+Ag(Br) collision data, so for my final figure I combine these two data sets. In Fig. 3, I compare S_2 with S_2^ϕ, where S_2^ϕ is constructed by putting all particles with $0<\phi<\pi$ in the L sub-bin and all particles with $\pi<\phi<2\pi$ in the R sub-bin. For the convenience of the reader, I present results for O and S collisions alone and for the combined event sample in Table I.

If I compare S_2 to scaled-factorial-moment data from e^+e^- collisions [6], I find that the correlations are roughly eight times stronger for O and S collisions. Comparison to data from πp and Kp collisions [7] gives similar results. Thus, nuclear collisions seem to produce anomalously large correlations that do not depend strongly on the sizes of the nuclei involved.

As these correlations are so large, I make the most conservative estimate possible of the signal from conversion of γ's from π^0 decays into e^+e^- pairs, only some of which can be observed. This is the major source of systematic error in these emulsion experiments. I find that, if I *optimize* the distribution of pseudorapidity separa-

TABLE I. $(dN/d\eta)(S_2-R)$ and $(dN/d\eta)(S_2^\phi-R)$ from O+Ag(Br) collisions, S+Ag(Br) collisions, and from the combined event sample.

Data	$\delta\eta=2$	$\delta\eta=1$	$\delta\eta=\frac{1}{2}$	$\delta\eta=\frac{1}{4}$	$\delta\eta=\frac{1}{8}$
S_2,O	0.42±0.18	0.62±0.23	0.62±0.28	0.97±0.34	1.35±0.39
S_2,S	0.45±0.20	0.53±0.24	0.85±0.27	1.10±0.27	0.98±0.35
S_2, all	0.43±0.14	0.57±0.17	0.76±0.20	1.05±0.21	1.12±0.26
S_2^ϕ,O	0.19±0.09	0.13±0.18	0.08±0.21	0.22±0.26	0.14±0.36
S_2^ϕ,S	0.19±0.10	0.26±0.18	0.49±0.20	0.59±0.24	0.45±0.30
S_2^ϕ, all	0.19±0.07	0.20±0.13	0.32±0.15	0.44±0.18	0.32±0.23

tions, 97% of the observed particles must come from these decays in order to reproduce the measured correlations. This is a strict lower limit, so it is very unlikely that this signal can be explained by systematic effects.

In summary, I have constructed S_2 and S_2^ϕ for O+Ag(Br) and S+Ag(Br) collisions at 200 GeV/nucleon. The results are essentially the same for the two types of collisions. The best results are obtained by using the exclusive formulations of the correlation functions and correcting for multiplicity on an event-by-event basis. The correlations observed are anomalously large, and should be looked at more closely in further studies of nuclear, proton, and lepton collisions.

I thank the KLM Collaboration for supplying these data, and especially P.S. Freier and C. J. Waddington for many useful discussions. This research was supported by the U.S. Department of Energy under Contract No. DOE/DE-FG02-87ER-40328. Computer facilities were provided by the Minnesota Supercomputer Institute.

*Address after 15 September 1991: Department of Physics, Kent State University, Kent, Ohio 44242.

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