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Intermittency in 200 GeV/nucleon S+S Collisions

P. Jacobs, M.A. Bloomer, and the WA80 Collaboration

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[a] Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA
[b] Gesellschaft für Schwerionenforschung, D-6100 Darmstadt, Fed. Rep. of Germany
[c] Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA
[d] KVI, University of Groningen, NL-9747 AA Gronigen, Netherlands
[e] University of Münster, D-4400 Münster, Fed. Rep. of Germany
[f] University of Lund, S-22362 Lund, Sweden
[g] Brookhaven National Laboratory, Upton, NY 11973, USA
[h] Kurchatov Institute, Kurchatov Square, 123182 Moscow, USSR
[i] University of Tennessee, Knoxville, TN 37996, USA
[1] now at: CERN, CH-1211 Geneva 23, Switzerland
[2] now at: Mercedes-Benz, D-7000 Stuttgart, Fed. Rep. of Germany
[3] now at: KVI, University of Groningen, NL-9747 AA Gronigen, Netherlands

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[a] *Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA*
[b] *Gesellschaft für Schwerionenforschung, D-6100 Darmstadt, Germany*
[c] *Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA*
[d] *KVI, University of Groningen, NL-9747 AA Gronigen, Netherlands*
[e] *University of Münster, D-4400 Münster, Germany*
[f] *University of Lund, S-22362 Lund, Sweden*
[g] *Brookhaven National Laboratory, Upton, NY 11973, USA*
[h] *Kurchatov Institute, Kurchatov Square, 123182 Moscow, USSR*
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[2] *now at: Mercedes-Benz, D-7000 Stuttgart, Germany*
[3] *now at: KVI, University of Groningen, NL-9747 AA Gronigen, Netherlands*

Abstract

We have studied one and two–dimensional intermittency in S+S collisions at 200 GeV/nucleon in a high statistics electronic measurement at the CERN SPS using pad–readout streamer tubes. We observe no intermittency signal beyond that produced by folding the Fritiof event generator with a detailed model of our detector. Even though the observed signal contains significant distortions due to experimental effects, we show that we are sensitive to intermittency in the collision.

Introduction

Short range fluctuations of charged particle phase space densities in high energy

collisions have been proposed as a signature of collective effects or of the dynamics of more elementary particle production [1]. However, such measurements are difficult to interpret because of the unavoidable additional fluctuations due to finite particle multiplicity, resonance production, and detector effects such as interactions with material and limited two-track resolution. Białas and Peschansky [2, 3] have suggested a means of suppressing the fluctuations due to finite multiplicity by calculating the mean scaled factorial moments of the multiplicity distribution. Given a total interval of (e.g. rapidity) Δy divided into M equal bins of size $\delta y = \Delta y/M$, the mean scaled factorial moment $\langle F_q \rangle$ of order q is defined as:

$$\langle F_q \rangle = \frac{1}{M} \frac{\sum_{m=1}^{M} \langle n_m(n_m-1)\ldots(n_m-q+1)\rangle}{\langle n \rangle^q}, \tag{1}$$

where n_m denotes the population of bin m, $\langle\cdots\rangle$ indicates an average over events, and $\langle n \rangle$ is the mean multiplicity within δy. A different definition of $\langle F_q \rangle$ has been given for a fixed total multiplicity[2], and care must be taken if dN/dy varies significantly within Δy[4]. However, eqn. 1 is correct for the present analysis. The dynamics of the particle production mechanism are then reflected in the dependence of $\langle F_q \rangle$ on δy. In particular, a mechanism with a self-similar ("branching") structure would exhibit a power law dependence:

$$\langle F_q \rangle \propto \delta y^{-\phi_q}. \tag{2}$$

This power–law dependence is known as *intermittency*, and the general study of the dependence of $\langle F_q \rangle$ on δy has come to be known by that name. ϕ_q, which is the slope in a plot of $ln(\langle F_q \rangle)$ vs. $-\ln(\delta y)$, has come to be known as the *intermittency index*, or simply the *slope*. Van Hove[5] has given an intuitive interpretation of ϕ_q. The probability P_q of finding q particles in a bin of size δy having mean population $\langle n \rangle$ is given by

$$P_q \propto \langle n \rangle^{q-\phi_q} \tag{3}$$

for $\langle n \rangle \propto \delta y \rightarrow 0$. In other words, a positive ϕ_q indicates a correlated (non–Poisson) population distribution in small bins.

Białas and Peschansky[2] proposed that particle production in a longitudinally expanding fluid of quark–gluon plasma has an underlying branching structure in rapidity, leading to clustering in rapidity of final state hadrons (i.e. intermittency in the multiplicity distribution). Others have suggested intermittency as a signal of a second order phase transition[6]. However, more elementary particle production mechanisms, such as the fragmentation of strings (e.g. [7] and references therein) or high energy jets[8], are also expected to produce intermittent final state distributions. Whatever the underlying physics, intermittency analysis has served as a sensitive statistical tool to compare particle production models to data. The hope is that, after accounting for all experimental effects, differences between models and data will point to new physics.

There have been extensive experimental investigations of intermittency in the last few years. For the case of e^+e^- collisions, almost all studies find agreement in intricate detail between data and commonly used particle production models[9, 10] (but see also

[11]). The situation with hadronic probes is much less clear. In particular, the question of intermittency in high energy heavy ion collisions is unsettled. The KLM[12] and NA35[13] collaborations report intermittency slopes that cannot be accounted for by common particle production models, and that increase with increasing dimensionality of the phase space partitioning. On the other hand, both the Helios-Emulsion Collaboration[14] and the EMU01 Collaboration[15] report no slopes beyond those accounted for by folding common particle production models with a model of experimental effects.

All of the reported heavy ion results are from visual experiments, with their attendant low statistics. This paper reports on results from the electronic heavy ion experiment WA80, which measured heavy ion collisions of S+S at 200 GeV/nucleon at the CERN SPS. Electronic experiments have the advantages over visual detectors of a cleaner trigger and much higher statistics. However, they suffer from reduced spatial resolution, leading to a more limited two–track separation, and from a reduced ability to distinguish backgrounds such as γ conversions and hadronic showering in matter. We have made a careful study of track reconstruction and background effects, and present both one and two–dimensional[8] intermittency analyses of S+S collisions at 200 GeV/nucleon.

WA80 had previously reported the observation of significant intermittency in ^{16}O–induced reactions at 200 GeV/nucleon[16]; however, because of an error in the track reconstruction and uncertainties in the detector calibration those results are incorrect. This paper presents a new analysis, based on a reconfigured and calibrated detector and a completely new analysis procedure.

Experimental Setup

The 1990 setup for the WA80 experiment is shown in Figure 1. The large area, high granularity streamer tube array[17] was used to measure multiplicity distributions. The mid–rapidity and zero–degree calorimeters[18] were used for triggering. The lead glass spectrometer was not used in this analysis. The streamer tubes were arranged in two planes perpendicular to the beam, each layer covered with 2x10^4 capacitively coupled pads of size 1x2 cm^2. Each layer had a detection efficiency of $\approx$90%.

The streamer tubes are of the Iarrocci type[19]. The pads are connected to discriminators so that a *yes/no* signal is generated, depending on the passage of a charged particle through or near the pad. The pads are arranged in groups of 160 on printed circuit boards of size 21x21 cm^2, with each board having a single threshold setting for all its pads. In calibration runs it was found that the passage of a single charged particle can induce a signal on a cluster of adjacent pads. For a given location on the detector there is a distribution of sizes and shapes of the single–particle clusters, and this distribution can vary over the face of the detector depending upon the local threshold setting and the mechanical coupling of the pads to the streamer tubes. The size of the single–hit clusters determines the two–track separation, which is the quantity that limits resolution for intermittency studies (see below).

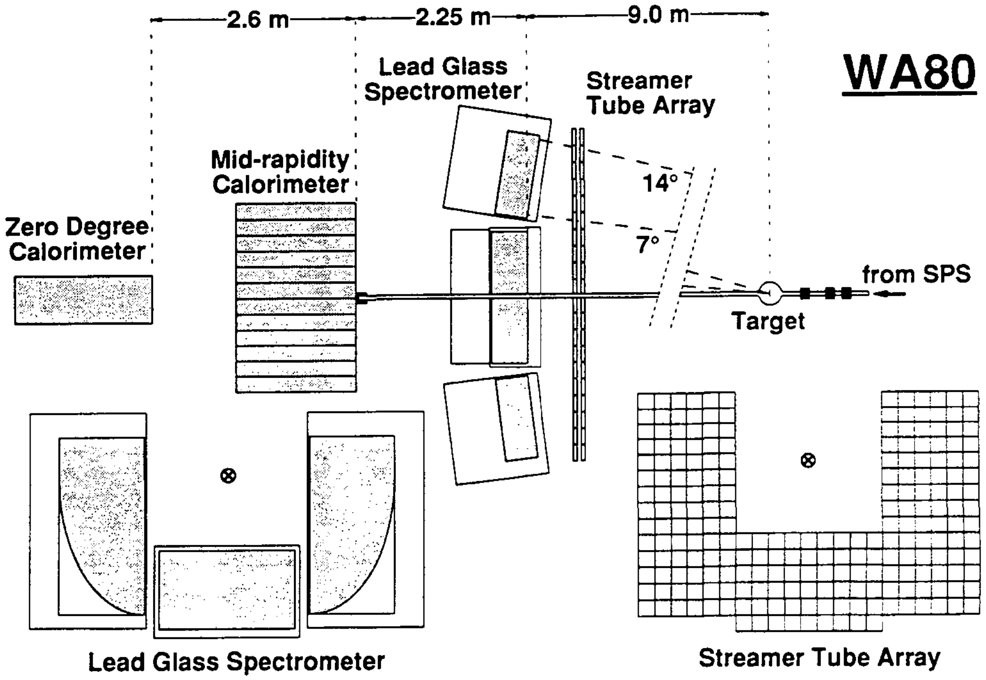

Figure 1: 1990 WA80 experimental setup

Data Analysis

Charged particle tracking was performed by requiring coincident hits (clusters) on both planes of streamer tubes, with the vector formed by the clusters pointing to the vicinity of the target. This procedure eliminated the main source of background clusters due to showering of high pseudorapidity reaction products in the beam pipe. A "horizontal-vertical" factorial moment analysis[15] was performed using tracks within the pseudorapidity interval $2.12 \leq \eta \leq 2.57$ ($\Delta\eta = 0.45$) and the azimuthal angle interval $-110° \leq \phi \leq 110°$ ($\Delta\phi = 220°$). These intervals were successively divided by integers: $\delta\eta = \Delta\eta/m$, for a one-dimensional analysis in η and $(\delta\eta = \Delta\eta/m) \simeq (\delta\phi = \Delta\phi/8m)$ for a two-dimensional analysis in η-ϕ, where $m = 1, 2, \ldots 8$. The bin multiplicities for a given subdivision of an event were summed to obtain the scaled factorial moments using eqn. 1. At least five events were required to contribute to a moment in order to calculate it at a given resolution[10]. Due to our narrow pseudorapidity coverage, no correction[4] for the variation of $dN/d\eta$ was necessary. To obtain the statistical error of the $\langle F_q \rangle$, factorial moments $\langle \tilde{F}_q \rangle$ were calculated for subsamples of ≈500 events. The variance of the distribution of $\langle \tilde{F}_q \rangle$ then provided an estimate of the statistical error of $\langle F_q \rangle$. Since the same events were used to calculate all $\langle F_q \rangle$ as a function of δy, the errors of $\langle F_q \rangle$ are correlated.

Peripheral and central events were selected by cuts on the energy observed in the mid-rapidity and zero degree calorimeters[18]. In the present analysis we have used 9.6×10^4 peripheral and 1.32×10^5 central S+S events.

Simulations

Experimental effects can generate or suppress the correlations that are present in the true multiplicity distribution of the collision. In order to assess these experimental effects, we have performed detailed simulations of the WA80 setup using the detector modelling program Geant V3.14 fed by events from the Fritiof event generator V1.7 [20]. In addition to modelling the generation or suppression of tracks due to interactions in matter, we have developed a model of the response of the streamer tube detector. As described above, the detector readout is segmented into readout boards (groups of 160 pads). Due to electronic and mechanical variations among the boards, the local response of the detector can vary. The response of any local region of the detector was determined from low multiplicity events in the actual physics runs, and was characterized by an efficiency and by the distribution of sizes and shapes of single–hit pad clusters observed in that region. This local response was then used in the simulation for the same region of the detector, pad hits were generated according to the cluster distribution, and the simulated events were passed through the same analysis chain that was used to process the raw data.

An approximate model of the WA80 trigger was developed, based on the geometrical acceptance of the mid–rapidity and zero degree calorimeters, to select central or peripheral events in the simulation in the same way as in the data analysis.

Results

Multiplicity distributions within the acceptance of the intermittency analysis for central and peripheral S+S collisions are shown for both data and simulations in Figure 2. Good agreement is obtained, showing that the Monte Carlo reproduces well the gross features of the multiplicity distribution, though the distribution for the data is slightly broader than that for the simulation for central events.

Factorial moments $\langle F_2 \rangle$ for both data and simulations of S+S collisions are shown in Figures 3 and 4 for one–dimensional (η) and two–dimensional (η–ϕ) intermittency analyses respectively. In these and all following intermittency plots, the $\langle F_2 \rangle$ of all distributions on a plot have been scaled so that their leftmost points have the same value. This permits the expansion of the vertical scale to show the differences in slopes between distributions. We choose this means of display of the data to emphasize the physically important parameter of the data (the slope) while suppressing the offsets in the magnitude of the $\langle F_2 \rangle$, which are modest between Monte Carlo and data. The slopes of the data are in all cases well matched by those of the Monte Carlo. The two–dimensional analyses (both model and data) show considerable sagging at small bin size for central events. This is due to the two–track resolution, as will be shown in the next section.

We conclude from Figures 3 and 4 that the data contains no intermittency beyond that contained in the simulation. It has been shown previously that for heavy ion collisions Fritiof contains essentially no intermittency[15]; the small slopes observed in the simulations are due to experimental effects such as γ conversion and showering in mate-

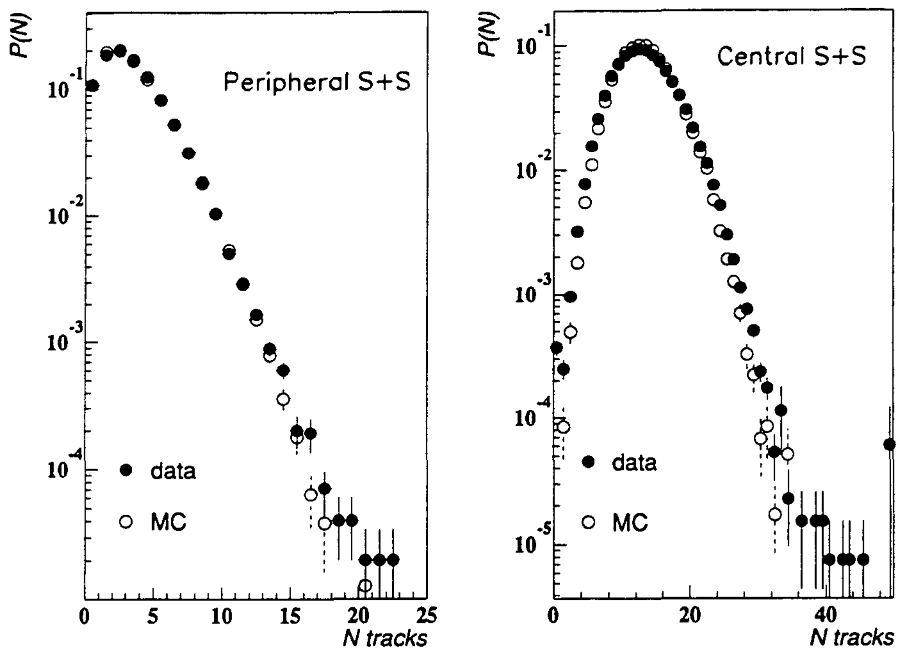

Figure 2: Probability distribution to obtain N tracks in the WA80 acceptance for peripheral (left panel) and central (right panel) S+S collisions. Filled points: data; open points: Monte Carlo.

rial, whose fluctuations are more apparent in the peripheral ($dN/d\eta \approx 13$) than central ($dN/d\eta \approx 50$) collisions. It remains to be shown that we have sensitivity to intermittency in the collision and that our results are not dominated by experimental effects. This will be done in the next section.

Alpha Model calculations

In order to obtain a deeper understanding of the experimental effects contributing to the observed dependence of $\langle F_q \rangle$ on δy, we have studied a more schematic simulation based on the Alpha Model [2] using the numerical prescription proposed in [21]. This is a simple, analytically solvable cascade model that generates truly intermittent distributions to arbitrarily small scale in phase space. It allows us to isolate and study experimental effects in an approximate way, independent of the complex simulation and reconstruction procedures used in the data analysis.

In the notation of [2], the Alpha Model slope is given by

$$\phi_q = \frac{log\langle W^q \rangle}{log\lambda}, \tag{4}$$

where W is a random function associated with each bin, $\langle \cdots \rangle$ denotes mean value, and λ is the number of subdivisions of a bin in each step of the cascade. The case of $\lambda = 2$ was studied in [2]. We have used $\lambda = 4$ in order to generate true two-dimensional intermittency distributions: given an initial phase space area $\Delta\eta\Delta\phi$, the bins of the first subdivision have area $\Delta\eta\Delta\phi/4$, those of the second subdivision $\Delta\eta\Delta\phi/16$, etc.

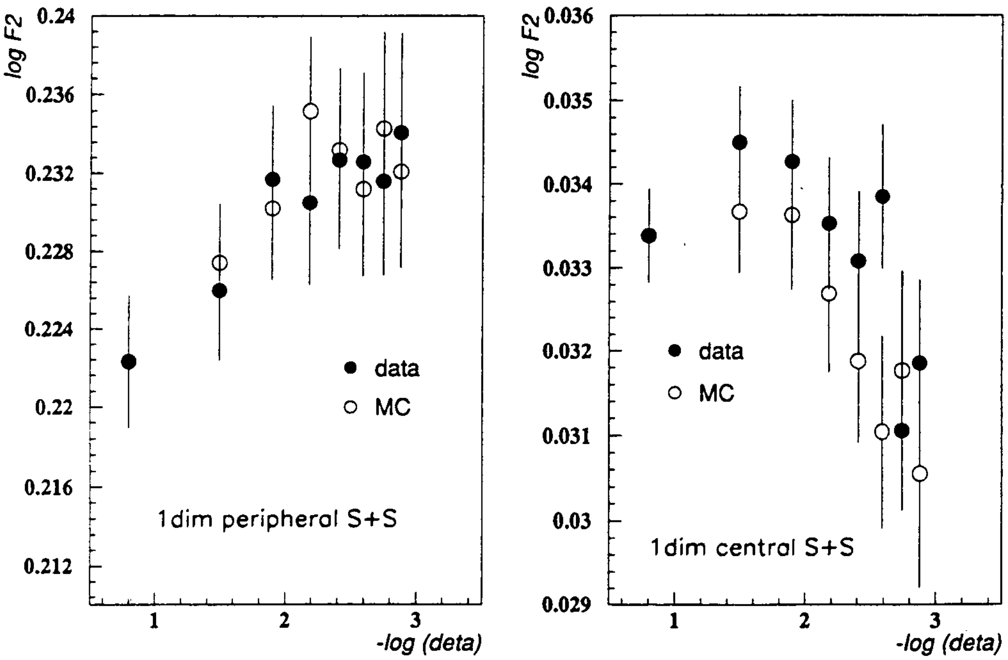

Figure 3: Log($\langle F_2 \rangle$) as a function of -log($\delta\eta$), for peripheral (left panel) and central (right panel) S+S collisions. Filled points: data; open points: Monte Carlo. The moments of the Monte Carlo calculation have been scaled so that the leftmost point agrees with that of the data. Note the extremely expanded vertical scale.

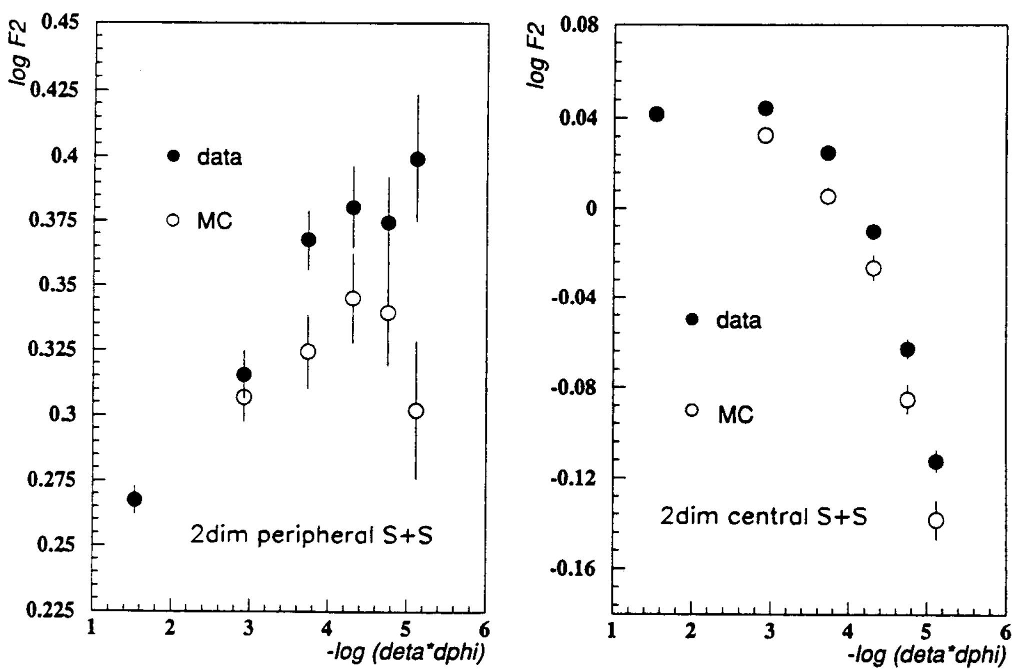

Figure 4: Log($\langle F_2 \rangle$) as a function of -log($\delta\eta\delta\phi$) for peripheral (left panel) and central (right panel) S+S collisions. Filled points: data; open points: Monte Carlo.The moments of the Monte Carlo calculation have been scaled so that the leftmost point agrees with that of the data. Note the extremely expanded vertical scale.

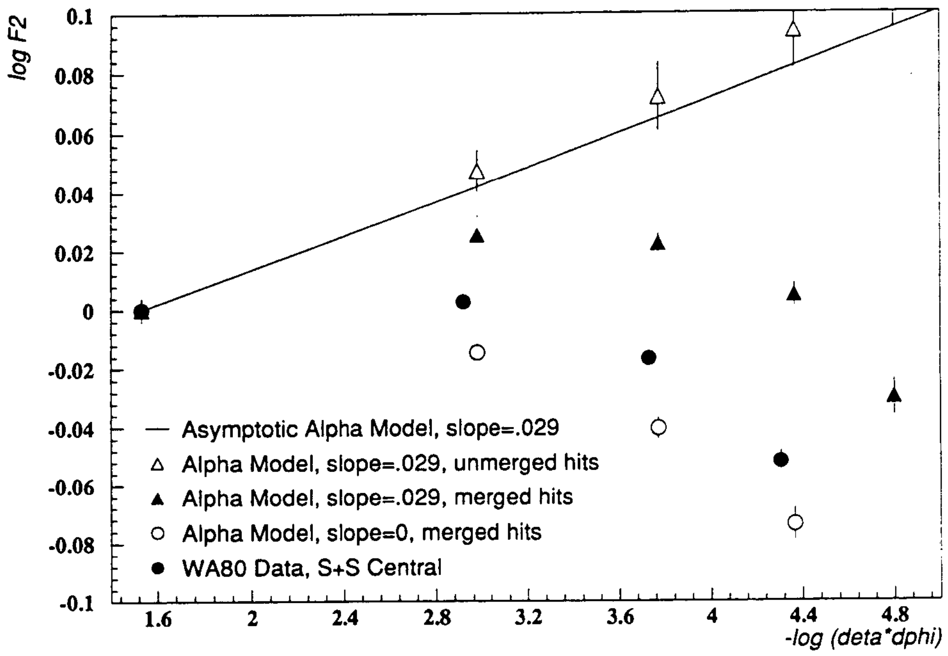

Figure 5: Log($\langle F_2 \rangle$) as a function of -log($\delta\eta\delta\phi$) for Alpha Model calculations described in the text. The closed circles are the WA80 data for central S+S events given in Figure 4. All $\langle F_2 \rangle$ distributions have been scaled vertically so that their leftmost point in the plot is zero.

For the two–dimensional case, particles were generated in η–ϕ space with $dN/d\eta = 50$. Eight generations of cascade were used (this is our practical computational limit). A large phase space interval was used for the particle generation, and the bin boundaries were shifted by a random amount in both η and ϕ to prevent artefacts due to the fixed phasing of the bins for particle generation and the bins for intermittency analysis[10]. The tracks with the WA80 acceptance were then projected onto a plane 8 m from the "vertex" and the hits could be altered in two ways:

efficiency 81% of the hits were kept to simulate the 90% efficiency of each detector plane and the requirement of a coincidence between them.

two–track resolution Tracks lying within a radius of 3 cm of each other were merged into a single hit to approximate the effect of finite single hit cluster size.

The resulting hit distributions were analysed for one and two–dimensional intermittency according to eqn. 1. As in the data analysis, at least five events were required to contribute to a moment in order to calculate it at a given resolution[10].

Results from calculations with the Alpha Model are given in Figure 5. The solid line corresponds to the intermittency slope for "semicentral" S+Em collisions reported in [12]. Using eqn. 4, Alpha Model parameters for the numerical calculations were chosen to reproduce this slope. The open triangles show the result of the calculation for the WA80

acceptance, but without efficiency or two-track resolution cuts. It is seen that neither the finite number of cascade generations in the numerical calculation nor the limited WA80 acceptance cause a deviation from the analytical (asymptotic) result. This is true to bin sizes smaller than those shown in the figure: at bin populations as small as 6×10^{-3} we do not observe the "empty bin effect", in contrast to results reported in [21]. The filled triangles show the same calculation as the open triangles, but with the 3 cm two-track resolution cut imposed. The distribution sags at small resolution, in qualitative agreement with the distributions seen in the data. A square on the detector of linear dimension 3 cm corresponds to $-\log(\delta\eta\delta\phi) \approx 7.8$; thus, the influence of finite two-track resolution is felt at a linear scale an order of magnitude larger than the size of the resolution itself, or two orders of magnitude for two-dimensional analysis. The open circles show the result of an Alpha Model calculation using the WA80 acceptance, but with zero slope (i.e. uncorrelated emission, or Poisson-distributed bin populations) and the 3 cm two-track resolution cut imposed. The corresponding distribution without the two-track resolution cut would be a straight line at $\log(\langle F_2 \rangle)=0$ (not shown). The efficiency cut does not measurably affect any of the distributions shown.

The main result of our Alpha Model calculations is given by comparing the open circles and the closed triangles in Figure 5. It is seen that we could easily distinguish zero slope from a slope of the size reported in [12].

The closed circles in Figure 5 are the WA80 data for central S+S events shown in Figure 4. These data lie between the calculations for slope=0 and slope=.029, and correspond to an input distribution with slope clearly less than .029. However, because of the crude nature of this detector model we do not estimate the value of this slope, nor do we give an uncertainty for the measured slope.

Conclusions

We do not observe intermittency (in either one or two dimensions) in S+S collisions at 200 GeV/nucleon, beyond that produced by the Fritiof event generator filtered through a detailed simulation of our detector. The distributions we observe show evidence for significant distortions due to experimental effects, principally two-track resolution. However, through model studies we have shown that we retain sensitivity to intermittency in the collision, but observe a two-dimensional slope much smaller than that reported in [12] for S+Em collisions at 200 GeV/nucleon.

As an experimental conclusion, we have shown the importance of two-track resolution as the limiting parameter of any non-visual detector used to study intermittency.

References

[1] *Sante Fe Workshop on Intermittency in High Energy Collisions, Los Alamos, USA, March 18-21, 1990*, ed. F. Cooper, R.C. Hwa and I. Sarcevic (World Scientific Pub-

lishing, 1991); for a brief overview, see L. Van Hove, Modern Phys. Lett. **A** Vol. 4, No. 19 (1989) 1867; for a theoretical overview, see R.C. Hwa, in *Quark-Gluon Plasma – Advanced Series on Directions in High Energy Physics*, vol. 6, ed. R.C. Hwa (Singapore: World Scientific Publishing, 1990), pg. 665.

[2] A. Białas and R. Peschanski, Nucl. Phys. **B273** (1986) 703.

[3] A. Białas and R. Peschanski, Nucl. Phys. **B308** (1988) 857.

[4] K. Fiałkowski et al., Acta Phys. Polon. **B20** (1989) 639.

[5] L. Van Hove, Mod. Phys. Lett. **A4** (1989) 1867.

[6] H. Satz, Nucl. Phys. **B326** (1989) 613.

[7] G. Gustafson and A. Nilsson, Z. Phys. **C52** (1991) 533.

[8] W. Ochs and J. Wosiek, Phys. Lett. **B214** (1988) 617.

[9] DELPHI Collaboration, Phys. Lett. **B247** (1990) 137.
OPAL Collaboration, Phys. Lett. **B262** (1991) 351.
ALEPH Collaboration, CERN–PPE/91–37.

[10] CELLO Collaboration, Phys. Lett. **B256** (1991) 97.

[11] TASSO Collaboration, Phys. Lett. **B231** (1989) 548.

[12] KLM Collaboration, Phys. Rev. Lett. **62** (1989) 733; Phys. Rev. **C40** (1989) R2449.

[13] NA35 Collaboration, I. Derado et al., Proc. Ringberg Workshop on Multiparticle Production, Ringberg Castle, Germany (1991) (World Scientific, to be published)

[14] HELIOS–Emulsion Collaboration, Phys. Lett. **B252** (1990) 303.

[15] EMU01 Collaboration, Phys. Rev. Lett. **65** (1990) 412; Z. Phys. **C49** (1991) 395; Phys. Lett. **B263** (1991) 539.

[16] WA80 Collaboration, Phys. Lett. **B221** (1989) 427.

[17] R. Albrecht et al., Nucl. Instr. Meth. **A276** (1989) 131.

[18] T.C. Awes et al., Nucl. Instr. Meth. **A279** (1989) 497.
G.R. Young et al., Nucl. Instr. Meth. **A279** (1989) 503.
WA80 Collaboration, ORNL Preprint 91-0331 (1991).

[19] E. Iarrocci, Nucl. Instr. Meth. **217** (1983) 30.

[20] B. Nilsson–Almqvist and E. Stenlund, Comp. Phys. Comm. **43** (1987) 387.

[21] P. Desvallées, R. Ouziel and R. Peschanski, Phys. Lett. **B235** (1990) 317.

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
TECHNICAL INFORMATION DEPARTMENT
BERKELEY, CALIFORNIA 94720