Title
CENTRAL"" NEEDS NOT MEAN ""COLLECTIVE""

Author
Bohrmann, S.

Publication Date
1981-05-01

LBL-12929 c.2

Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

Presented at the Fifth High Energy Heavy Ion Study, Lawrence Berkeley Laboratory, University of California, Berkeley, CA, May 18-22, 1981; and to be published in the Proceedings

"CENTRAL" NEEDS NOT MEAN "COLLECTIVE"

Steffen Bohrmann

May 1981

NUCLEAR SCIENCE DIVISION

Prepared for the U.S. Department of Energy under Contract W-7405-ENG-48

DISCLAIMER

Contribution for the Proceedings of the 5th High Energy Heavy Ion Study
Berkeley, CA, 1981

"CENTRAL" NEEDS NOT MEAN "COLLECTIVE" *

Steffen Bohrmann
Nuclear Science Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

ABSTRACT

Spectra of high momentum protons from high energy nuclear collisions are analyzed in terms of a simple statistical model: independently interacting groups of nucleons contribute incoherently. The nucleon momentum distributions within one group follow phase space. It can be shown that

1) the spectra can clearly be decomposed into spectator and participant contributions,
2) the average size of the nucleon groups is very insensitive to impact parameter restrictions.

The latter finding suggests that (at least for the high momentum tails of measured spectra) central collisions do not necessarily enhance the chance for seeing indications of effects due to coherence in the interaction of a larger number of particles ("collective effects").

* Work supported by NATO-fellowship, Deutscher Akademischer Austauschdienst, Bonn, Fed. Rep. of Germany, by Bundesministerium für Forschung und Technologie, Bonn, Fed. Rep. of Germany, and the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract W-7405-ENG-48.

The statistical model of high energy nuclear collisions as introduced by J. Knoll [1] has proven to be a valuable tool for studying the high momentum parts of inclusive spectra [2]. Its main ingredients are:

1) geometrically defined groups of nucleons interact independently from each other

2) momentum distributions within one group are determined by phase space.

Formally, the one-nucleon inclusive cross section is written as an incoherent sum over contributions from ensembles containing M nucleons of the projectile A and N nucleons of the target B:

$$\varepsilon \frac{d^3\sigma}{dp^3} = \sum_{M,N} (M+N)\, \sigma_{AB}(M,N)\; F_{MN}(\vec{p}) \quad . \tag{1}$$

Each contribution is factorized into a formation cross section $\sigma_{AB}(M,N)$ (determined by geometry) and a momentum distribution $F_{MN}(\vec{p})$ (determined by phase space). The factor (M+N) accounts for the relative weight of the different ensemble sizes. - Further details of the model are given in [1,2].

There is a number of implications which can be derived from the apparent success of this model explaining a large amount of experimental data. These will be discussed elsewhere [3]. Here we want to concentrate on some interesting consequences derived from the comparison between model calculations and measured proton spectra from high energy nuclear collisions in kinematical regions inaccessible to single nucleon-nucleon collisions. Such spectra (protons being scattered to high momenta at 180° laboratory angle) have been published recently [4]; fig.1 shows an example. Obviously, there are two different components contributing to the spectrum. One possible interpretation is that this structure is a reflection of the subdivision of the colliding nuclei into participant (geometrically overlapping) and spectator parts; a widespread concept among reaction dynamical models. The statistical model as it is designed describes participants only and in fact is only able to reproduce the high momentum part of the observed spectrum (curve "Σ" in fig.1). Thus

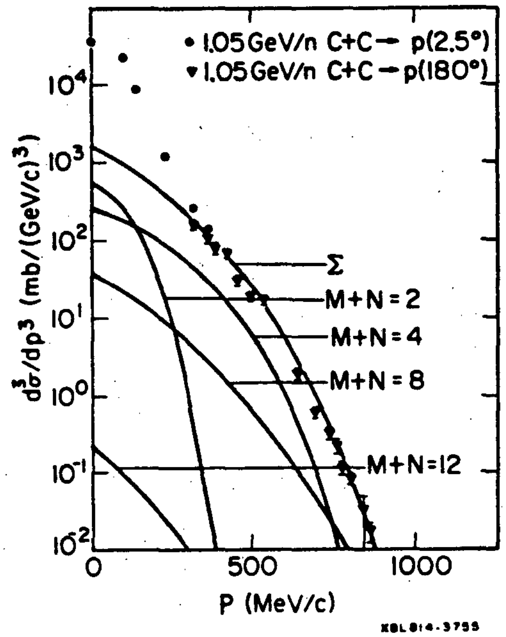

Fig.1. Experimental proton spectrum in comparison with a statistical model calculation. The 180° data are shown in the laboratory frame, the 2.5° data have been transformed to the projectile rest system [4]. The model prediction (curve "Σ") has been decomposed into the contributions of nucleon groups of different size.

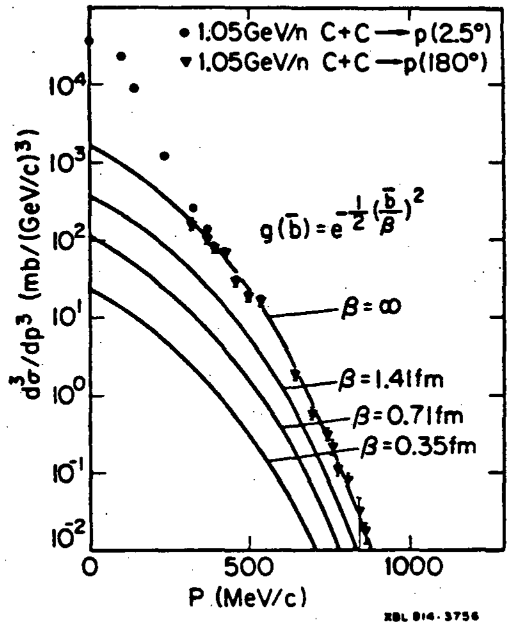

Fig.2. The influence of the restriction to central collisions on the outcome of the model calculation. The parameter β is the width of the Gaussian weight for the impact parameter $\vec{b}$.

we interpret the difference between our prediction and the measured data at low momenta as the contribution of the decay of the spectator parts: the two-component structure of the spectrum is simply due to the different decay schemes of participants and spectators.

Fig.1 shows that the shape of the (participant part of the) spectrum strongly depends on the size M+N of the group the observed proton has been belonging to. From the similarity of shapes it can be deduced that the main contribution comes from groups containing four nucleons. This is a rather small number; especially if one is looking for signatures of "collective effects" (effects to which several or many nucleons contribute coherently) one would rather like to look at data representing the mutual interaction of a larger number of nucleons. One hope has been that this can be accomplished by restricting the interactions to (nearly) central collisions, a restriction which is feasible experimentally (cf. [5] e.g.). The changes occuring when going from impact parameter averaged data to data from central collisions can be studied in the statistical model by introducing a Gaussian weight for the impact parameter $\vec{b}$ with a variable width β [6]. Fig.2 shows that except for a change in normalization the spectra of backward scattered protons are practically independent of impact parameter restrictions: the average nucleon group size does not seem to change significantly. This is surprising at first as one intuitively would expect major changes. Fig.3 shows that major changes do in fact occur if one looks into the details

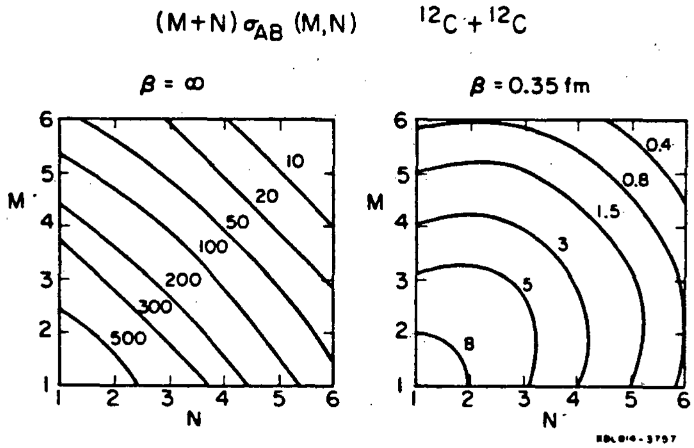

Fig.3. The weight of different combinations of projectile- and target-nucleon numbers in the inclusive cross section eq.1 in millibarns. Left: impact parameter averaged. Right: central collision. The parameter β has the same meaning as in fig.2.

of the group size distribution: the two dimensional plot shows the weight with which a certain group size contributes to the inclusive spectrum (cf. eq.1) as a function of projectile nucleon number M and target nucleon number N. Averaged over impact parameter the distribution is very flat perpendicular to the main diagonal, but it becomes lined up along the main diagonal for central collisions: the groups become more symmetric, i.e. are more likely to contain equal numbers of projectile and target nucleons. Despite these changes it turns out, however, that the mean of the distributions, the average group size, is practically the same in both cases: it increases by about 10% only! Table 1 shows that

Table 1. Average nucleon group size for various projectile-target-combinations and the influence of impact parameter restrictions.

	β [fm]	$\overline{M+N}$
$^{12}C + {}^{12}C$	∞	3.8
	0.35	4.2
$^{40}Ca + {}^{40}Ca$	∞	5.4
	0.70	6.1
$^{20}Ne + {}^{238}U$	∞	7.0
	1.70	9.4
$^{238}U + {}^{238}U$	∞	9.9
	1.26	11.0

this is true for heavier systems as well. Though the effect is more pronounced for an asymmetric system, it still is not very big: about 30% for Ne+U.

One can argue that this result is merely due to the linear geometry concept applied and thus completely model dependent. The above finding, however, has found support recently by a cluster analysis of three-dimensional cascade calculations [7]. Again the authors find a striking insensitivity of the mean cluster size on impact parameter restrictions (cf. their fig.4).

It should be mentioned that all this does not mean that there is no difference between peripheral and central collisions. On the contrary it is undoubtedly true that the reaction mechanism is largely different in these two cases. Rather, the claim is that the transition from impact parameter averaged data to data from central collisions is much less dramatic than expected.

In conclusion it can be said that -at least for the high momentum components of spectra- there exists a remarkable insensitivity to impact parameter restrictions. Going over to central collisions does hardly increase the number of mutually interacting nucleons and thus -if one believes in a kind of proportionality between nucleon number and buildup of "collective" effects- it does hardly increase the chance for finding signatures of some kind of "collectivity".

REFERENCES

[1] J.Knoll, Phys.Rev. C20 (1979) 773

[2] S.Bohrmann and J.Knoll, Nucl.Phys. A356 (1981) 498
J.Knoll, GSI-Nachrichten 4-81

[3] J.Knoll and S.Bohrmann, to be published

[4] J.V.Geaga et al., Phys.Rev.Lett. 45 (1980) 1993

[5] S.Nagamiya et al., Phys.Rev.Lett. 45 (1980) 602
A.Sandoval et al., Phys.Rev.Lett. 45 (1980) 874

[6] J.Knoll, Nucl.Phys. A343 (1980) 511

[7] J.Cugnon, J.Knoll, J.Randrup, Nucl.Phys. A360 (1981) 444

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