SCALING OF MULTIPLICITY DISTRIBUTIONS IN pn INTERACTIONS AT HIGH ENERGY

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Data on pn multiplicity distributions extracted from pd interactions at 400 GeV/c have been analysed with respect to their scaling behaviour. Results are compared with pn distributions derived from other pd experiments in the energy range 100—400 GeV. The consequence of the observations on the semi-inclusive scaling hypothesis and Mueller-Regge approach is discussed.

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1. Introduction

Recent interest in the properties of pn multiplicity distributions from experiments on deuterium target has grown due to the availability of neutron target effects. In our previous publications [1] it has been shown that the extraction of pn distributions from experiments in deuterium bubble chamber can' be successfully effected through a semi empirical model. The evaluated parameters of pp multiplicity distributions derived from deuterium experimental data has shown that these are compatible with those from hydrogen bubble chamber data. It would therefore be worthwhile to look into other characteristics of the pn multiplicity distributions extracted from pd experiments in order to search for their scaling behaviour.

The semi-inclusive scaling hypothesis [2] and Muelle-Regge view point [3] provided contrasting asymptotic predictions for the energy dependence of the multiplicity distributions obtained from high energy interactions. The prediction of semi-inclusive scaling hypothesis is based on arguments which are explicitly asymptotic in nature and therefore involves approximations which are probably not justified in the analysis of data at comparatively low energies. The Regge-pole dominance view point, as embodied in the Mueller–Regge approach, in its applicable form, gives the multiplicity distribution in terms of certain correlation parameters and predicts that these should asymptotically grow linearly with $\ln s$. The data from different experiments were reported to be in agreement with the

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prediction of semi-inclusive scaling hypothesis. However, leading particle effect [4] has been successful to provide a fitting of comparatively low energy (below 50 GeV) data with the semi-inclusive scaling [5]. But this trend of data has been negated by results from ISR [6] and also very recently by the $\bar{p}p$ collider data [7]. Also, Feynman Scaling, which served as ingradient to semi-inclusive scaling, has been shown [6, 8] to be violated.

This situation calls, therefore, for a detailed study of the problem. Slattery [5] covered energy up to 300 GeV for only pp interaction data from Hydrogen Bubble Chamber (HBC) and that also without subtracting the leading particle. In the study of the ISR results, Thome et al. [6] have pointed out that the leading particle may play a role. It is therefore necessary to study the nature and properties of multiplicity distributions in pn interactions from Deuterium Bubble Chamber (DBC) data at 400 GeV and at other energies in their different aspects both with and without the leading particle.

In this paper we present our results on the pn data extracted from DBC experiment at 400 GeV/c performed at FNAL. The number of events has been increased by over a factor of two from our previous publication [1]. We used pn data extracted from DBC experiments at other energies from 100 GeV [9, 10, 11]. The analysis has been performed to look into the behaviour with and without the leading particle.

2. *Data and analysis*

The data on pn multiplicity distribution extracted in this experiment are given in Table I and are plotted in Fig. 1(a). In Fig. 1(b) we show the corresponding odd- and even-prong distributions obtained from simulated pd distributions assuming normally distributed number of events as shown in Table II.

One of the predictions of the semi-inclusive scaling hypothesis is the energy independence of the momenta

$$C_q = \langle n^q \rangle / \langle n \rangle^q,$$

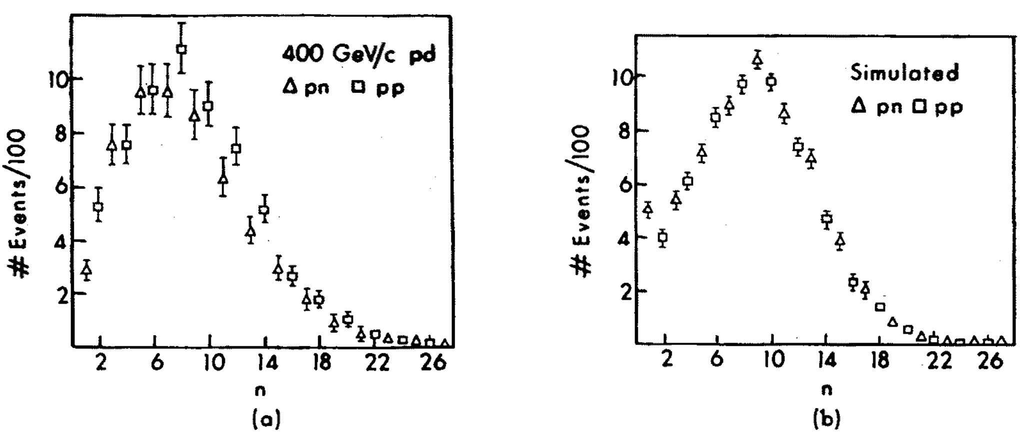

Fig. 1. (a) pn and pp multiplicity distributions from pd interaction at 400 GeV/c; (b) odd- and even-prong distributions from simulated 400 GeV/c pd data

TABLE I

pn and pp multiplicity distributions at 400 GeV/c after correcting for double scattering in pd interactions

Multiplicity (n)	No. of events	
	pn	pp
1	283±37	
2		527±62
3	749±68	
4		751±72
5	947±92	
6		959±89
7	945±104	
8		1110±90
9	860±93	
10		897±85
11	627±69	
12		741±72
13	430±47	
14		516±50
15	292±34	
16		259±37
17	171±37	
18		176±23
19	85±14	
20		106±14
21	42±12	
22		43±9
23	23±5	
24		16±8
25	9±2	
26		4±1
27	9±8	
28		2±2

where

$$\langle n^q \rangle = \sum_n n^q \sigma_n / \sigma_{\text{inel}}$$

is the q^{th} moment of multiplicity distribution and $q = 2, 3, 4, \ldots$ The constants C_q are asymptotically related to the function given by

$$\sigma_n/\sigma_{\text{inel}} \xrightarrow[s\to\infty]{} (1/\langle n \rangle)\psi(n/\langle n \rangle).$$

This form of the semi-inclusive scaling hypothesis does not take into account the leading particle effect. We have assessed the contribution of leading particle by the parameter α [4] from the minimum χ^2 fitting of $(\mu_N)^{1/N}$ graphs shown in Fig. 2 and found that to be numerically equal to unity. The values used for this are shown in Table III.

TABLE II

Simulated odd- and even-prong multiplicity distributions obtained from normally distributed variable generator (see text)

Multiplicity (n)	No. of events	
	Odd-prong	even-prong
1	511±22	
2		405±20
3	547±23	
4		620±24
5	721±26	
6		850±29
7	900±30	
8		986±31
9	1073±32	
10		992±31
11	865±29	
12		747±27
13	700±26	
14		475±21
15	392±19	
16		241±15
17	206±14	
18		140±11
19	82±9	
20		52±7
21	23±4	
22		18±4
23	8±2	
24		4±2
25	1±1	
26		1±1
27	1±3	

Fig. 3 shows the plots of C_q's (q from 2 to 5) against $P_{\rm lab}$ ranging from 100 to 400 GeV/c for pn distributions with and without the leading particle. Still higher C-moments are not used because errors in those are highly correlated and so one gains little information from their comparison. On comparing these two sets of figures it can be seen that with either way of representation, the energy independence of the moments is fairly valid. This means that the leading particle does not play a dominant role. The data, however, show a general agreement with semi-inclusive scaling.

According to Mueller–Regge approach, the first two Mueller correlation parameters f_2 and f_3 should show a linear growth with $\langle n\rangle$. In terms of the moments $\langle n^q\rangle$, these parameters are given as

$$f_2 = \langle n^2\rangle - \langle n\rangle (1+\langle n\rangle),$$

$$f_3 = \langle n^3\rangle - 3\langle n^2\rangle (1+\langle n\rangle) + \langle n\rangle [2+\langle n\rangle (3+2\langle n\rangle)].$$

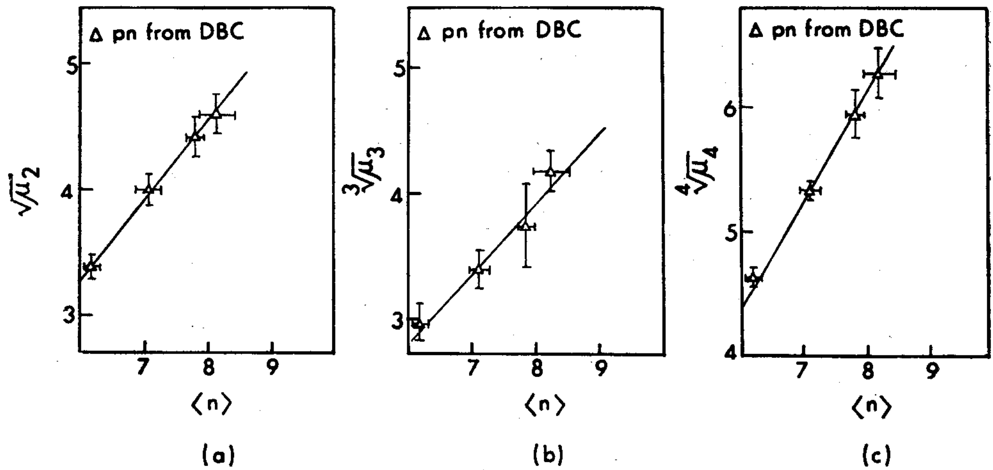

Fig. 2. Average multiplicity $\langle n \rangle$ variation of (a) $\sqrt{\mu_2}$; (b) $\sqrt[3]{\mu_3}$; and (c) $\sqrt[4]{\mu_4}$ for pn interactions from DBC data. The straight lines are the linear fits to the data

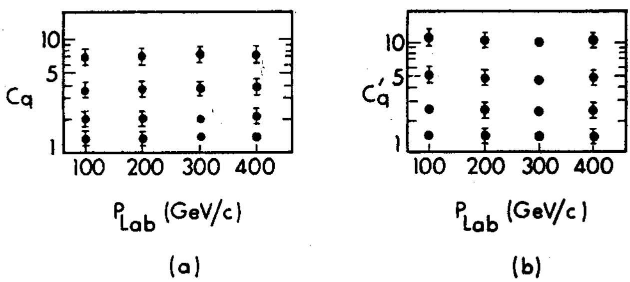

Fig. 3. Momentum variation of the C-moments for pn interactions extraction from pd data (a) without subtracting the leading particle ($C_q = \langle n^q \rangle / \langle n \rangle^q$ and (b) after subtracting the leading particle ($C_q = \langle (n-1)^q \rangle / \langle n-1 \rangle^q$)

TABLE III

Average multiplicity $\langle n \rangle$ dependence of the roots of central moments $(\mu_N)1/N$ (see text) for pn data from DBC experiments

$\langle n \rangle$	6.19 ± 0.12	7.11 ± 0.14	7.84 ± 0.15	8.20 ± 0.41
$\sqrt{\mu_2}$	3.37 ± 0.08	4.00 ± 0.11	4.41 ± 0.15	4.59 ± 0.15
$\sqrt[3]{\mu_3}$	2.97 ± 0.13	3.39 ± 0.15	3.74 ± 0.32	4.17 ± 0.29
$\sqrt[4]{\mu_4}$	4.63 ± 0.05	5.32 ± 0.05	5.94 ± 0.19	6.28 ± 0.20

The corresponding parameters excluding the leading particle can be readily obtained by introducing the moments $\langle (n-1)^q \rangle$.

The energy independence of C_q's and the general agreement of data with semi-inclusive scaling can further be evaluated by expressing the above Mueller correlation parameters in terms of these moments. When expressed in terms of C_q's the correlation parameters are related through an adjustable parameter γ_q and the relations show a nonlinear behaviour [5].

Figures 4(a) and (b) show the variation ofthe parameters f_2 with $\langle n \rangle$ and $\langle n-1 \rangle$ for pn data derived from DBC experiments with and without the leading particle. It is seen that in either way of representation, the data do not show noticeably different character thereby meaning that the contribution of the leading particle is not very important

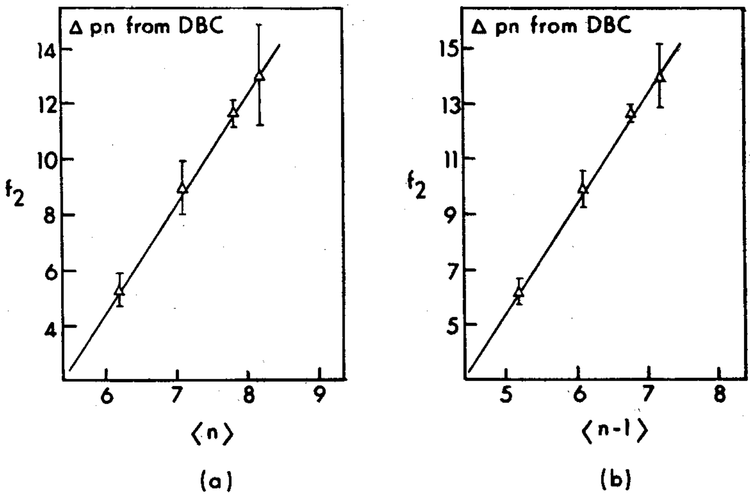

Fig. 4. Multiplicity dependence of the Mueller correlation parameter f_2 for pn from DBC data (a) without excluding the leading particle and (b) after excluding the leading particle

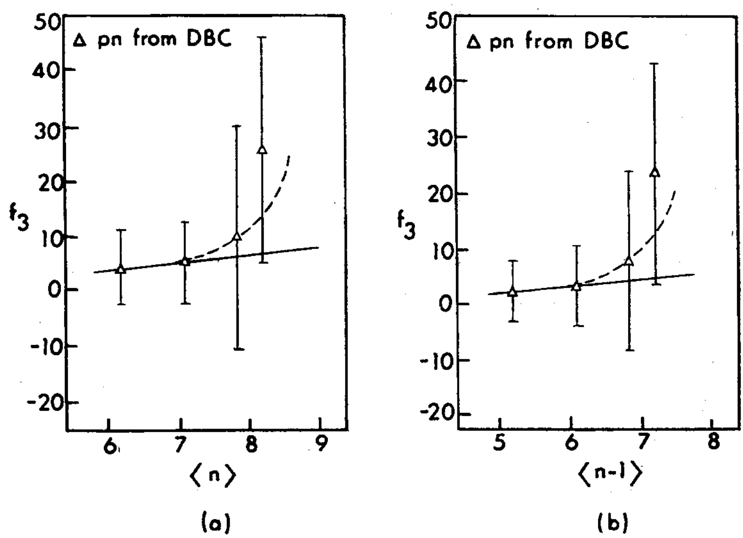

Fig. 5. Multiplicity dependence of the Mueller correlation parameter f_3 from DBC data (a) without excluding the leading particle and (b) after excluding the leading particle. The solid lines show the predictions of Mueller–Regge and the dashed lines show the predictions from the semi-inclusive scaling hypothesis

here. It is clear from Figs 4(a) and (b) that for pn interactions the variation of f_2 with either $\langle n \rangle$ or $\langle n-1 \rangle$ is linear. But in Figs 5(a) and (b) the variation of f_3 for the same is not linear at all. The variation of f_3 is also faster than predicted by semi-inclusive scaling assuming the energy-independence of the adjustable parameters γ_q's used in the calculations.

3. Conclusions

This analysis of the multiplicity distribution of pn interactions derived from pd data is the first attempt to study their scaling behaviour. The main observations of this study are:

The study failed to detect any perceptible role played by the leading particle in pn multiplicity distributions.

The energy independence of the *C*-moments for pn interactions agrees with the predictions of the semi-inclusive scaling hypothesis.

The increase of f_2 with $\langle n \rangle$ and $\langle n-1 \rangle$ for pn interactions is compatible with Mueller–Regge view point.

The increase of f_3 with $\langle n \rangle$ and $\langle n-1 \rangle$ for pn interactions show no compatibility with either semi-inclusive scaling or Mueller-Regge view point.

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