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PARTICLE PRODUCTION IN ANNIHILATION PROCESSES

I. BARYON NUMBER *

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ABSTRACT

The importance of annihilation processes as clean tests of models for particle production is stressed. Multiperipheral concepts are used to derive successful sum rules for annihilation cross sections and their accompanying inclusive distributions. These sum rules allow Feynman scaling and the Mueller Regge analysis to be carried over into the annihilation channel. They are further utilized to define a no parameter multiperipheral model for baryon number annihilation. This model is shown to provide a remarkably successful description of the gross features of the annihilation process from annihilations at rest up to the highest explored energies.

I INTRODUCTION

In the past few years, much effort has been devoted to the study of many particle production mechanisms in strong interactions. In these studies it has been customary to develop a theory of one such mechanism and then test it against the complete set of produced particle spectra in inelastic reactions. However, while the results of these studies are often promising, it is probable that the inelastic cross section involves not one but several production mechanisms; and present theory is unsure of the correct description (and perhaps even the definition) of single production mechanisms. The major point of this paper is to emphasize the feasibility of isolating parts of these spectra which receive contributions from only one well defined mechanism; so that theoretical descriptions of production mechanisms may be tested before the more difficult task of assessing a mechanism's contribution to the total cross section is undertaken.

Most proposed production mechanisms are generalizations of the concept of crossed channel exchange so useful in describing elastic reactions: the same exchanges are assumed to occur with particles produced "off" them. We propose the name inclusive exchange for this process, the exchange of a specified particle (or Regge trajectory) between the incident particles with any number of pions produced "off the exchange". In Fig.I we illustrate two current models for inclusive exchange; the disassociative model in which pions are produced in two clumps at the ends of a single exchange[1], and the multiperipheral model with pions produced singly by an iterated exchange[2,3]. To graphically represent inclusive exchange in an unbiased way, we will suppress produced pions and denote only quantum carrying particles, with an assumed sum over numbers of pions emitted "along each exchange" (see Fig.II). In this language the diffractive and multi-Regge models[3] for the total cross section are described as the "disassociative Pomeron" and the "multiperipheral secondary trajectory" exchange models respectively, a terminology which illustrates the twofold difference in philosophy both as to the dominant exchange and the correct description of production "off an exchange."

The simplest accessible process dominated by a single inclusive exchange is baryon number annihilation into pions, which will be our major interest in this paper. Although the annihilation cross section decreases with increasing energy, it is quite large at accelerator energies (20 mb at an incident momentum of 7 (GeV/c)) and decreases slowly (roughly like $s^{-.5}$). And particle production in annihilation is copious; the average charged pion multiplicity for annihilation at rest exceeds that for pp interactions at 30 (GeV/c). Thus it offers a fruitful field for the inclusive cross section analysis now being applied to total cross sections. In Section II we derive Feynman scaling predictions for annihilation that such an analysis would immediately test.

As a further sample of the possible physics, we note the often made statements that annihilations are well described by the statistical model even above at rest and that the average transverse momentum of produced pions is not limited. Unfortunately, as we show in Section III, already extant experimental evidence contradicts this last statement.

Our procedure in this paper is to derive and test, in Section II, sum rules for the annihilation cross sections, both total and inclusive. These sum rules can be interpreted as the generation[4] of a set of exchange degenerate Regge trajectories by inclusive baryon exchange. Most importantly, they allow both the complete set of Feynman scaling[5] predictions and the Mueller Regge analysis[6] to be carried over to the annihilation channel. In Section III, a no-parameter multiperipheral model, based in part on these sum rules, is developed and shown to provide a remarkably successful description of the existing annihilation data. In Section II a brief mention is made of the application of these sum rules to the hypercharge annihilation channel, a full discussion of which is postponed to a later paper. Our results are summarized in Section IV.

II - SUM RULES AND SCALING

In this section we derive and test sum rules for baryon number and hypercharge annihilation processes. Our major assumption in these derivations is the multiperipheral model; less quantifiable assumptions are made and discussed at length below.

Consider the $\bar{n}n$ and nn total cross sections. In the terminology of Section I, their inclusive exchange diagrams differ only on the right hand side where antibaryon ($\bar{B}$) and baryon (B) exchanges appear, respectively. In Fig. IIIa we present the multiperipheral model diagrams for the two cross sections (which are amplitudes squared and hence have two t channel lines). There are then two types of contributions to the two cross sections:

1) Sets of exchanges (see Fig.IIIa) that include a pair of inclusive meson exchanges (MM'). These diagrams contribute to both $\sigma_{\bar{n}n}$ and σ_{nn} with equal magnitude, and with a relative sign determined by the charge conjugation properties of the pair (MM').

2) The baryon number annihilation process (see Fig.IIIb), which contributes only to $\sigma_{\bar{n}n}$ and which we denote by $\sigma_{(\bar{n}n)_A}$.

The crucial point of our argument is that the contribution, to the total cross section difference, $(\sigma_{\bar{n}n}-\sigma_{nn})$, of those meson pairs even under charge conjugation is identically zero. From the terms of type 1, only those with meson pairs odd under charge conjugation contribute to $(\sigma_{\bar{n}n}-\sigma_{nn})$. In particular, no diagonal pairs (MM) contribute to the cross section difference. And, for nondiagonal pairs, the sum over different numbers of produced pions implied in Fig.III involves products of coupling constants, $g_{M\pi M}g_{M'\pi M'}$, instead of the squares, $g_{M\pi M}{}^2$, that appear for diagonal pairs. Since these products are not of definite sign, cancellations are to be expected in the sum over different final states and different pairs (MM'). Thus, the dominant contribution to the cross section difference should be that of type 2.

This implies

$$\sigma_{\bar{n}n} - \sigma_{nn} = \sigma_{(\bar{n}n)_A} \qquad (1)$$

where we should take the quality more seriously at high energy, when the sum over produced pions involves many final states and more possible cancellations for type 1. contributions.

Before developing this argument further, we should point out one possible objection to eq.(1). Some of the final states summed over in the annihilation process may contain a meson resonance with a substantial $\bar{N}N$ decay probability (see Fig.IIIc). These final states would not be counted in the experimentally determined annihilation cross section and eq.(1) would appear violated. However, at least for annihilation processes, substantial contributions from such final states can be safely ruled out.

For the experimentally accessible cross sections ,$\bar{p}p$ and pp, there is the additional complication of the differing charges of the $\bar{p}$ and p. The correct version of eq.(1) now involves, on the right hand side, both baryon number annihilation and charge annihilation minus the overlap between these two annihilations:

$$\sigma_{\bar{p}p} - \sigma_{pp} = \sigma_{(\bar{p}p)_A} + \sigma_{\bar{p}p\to\text{neutrals}} - \sigma_{pp\to\text{neutral mesons}} \qquad (2)$$

$$= \sigma_{(\bar{p}p)_A} + \sigma_{\bar{p}p\to\bar{n}n+\text{neutrals}} \qquad (3)$$

However, an argument can be advanced to simplify eq.(3). Arguments similar to those leading to eq.(1), if applied with charge as the tagged quantum number (instead of baryon number), yield

$$\sigma_{pn} - \sigma_{pp} = \sigma_{pn\to np+neutrals} \qquad (4)$$

where, by $\sigma_{pn\to np+neutrals}$, we denote the cross section for charge exchange between the two incoming baryon lines, with no other charged particles emitted. Now exchange degeneracy[7] (here experimentally verified) predicts 0. for the left hand side of eq.(4) and the right hand side is exactly equal to $\sigma_{\bar{p}p\to\bar{n}n+neutrals}$:

$$0 = \sigma_{\bar{p}p\to\bar{n}n+neutrals} \qquad (5)$$

Experimentally, this subsidiary argument is justified: $\sigma_{(\bar{p}p)_A}$ is substantially greater than $\sigma_{\bar{p}p\to 0\ prongs}$ (see Table Ia). Thus, eq.(3) becomes

$$\sigma_{\bar{p}p} - \sigma_{pp} = \sigma_{(\bar{p}p)_A} \qquad (6)$$

a relation long known to approximately true empirically[8], and which we test, and find successful, in Table I.

Eq.(6) is intuitively appealing in that it provides an immediate reason for the inequality $\sigma_{\bar{p}p} > \sigma_{pp}$; the annihilation channel is open to the former process and not the latter. Alternatively, it can be viewed as the generation of the $(\omega+\rho)$ pair of Regge trajectories, which dominate the left hand side of eq.6, by annihilation. This interpretation is in excellent agreement with exchange degeneracy; a secondary trajectory contribution to $\sigma_{\bar{p}p}$ but none to σ_{pp}. It is worth noting that, in a disassociative model for inclusive exchange, one would naively expect (unless strong couplings to many body "clumps" are introduced) an energy dependence for $\sigma_{(\bar{p}p)_A}$ similar to that of single baryon exchange (approximately like s^{-2}) instead of the $s^{-.5}$ energy dependence implied by eq.6 and $(\rho+\omega)$ dominance of its left hand side, and confirmed by the experimental data.

The same arguments can be applied to any subset of the $(\bar{p}p-pp)$ cross section difference, so long as that subset contains enough final states for the assumption of cancellation of contributions of type 1. to be valid. Thus

$$\sigma_{\bar{p}p\to n\text{ prongs}} - \sigma_{pp\to n\text{ prongs}} = \sigma_{(\bar{p}p)_A\to n\text{ prongs}} \qquad (7)$$

relates the various n charged prong cross sections; and the single particle inclusive distributions are related by

$$\left.\frac{d\sigma}{d^3p}\right|_{\bar{p}p} - \left.\frac{d\sigma}{d^3p}\right|_{pp} = \left.\frac{d\sigma}{d^3p}\right|_{(\bar{p}p)_A} \qquad (8)$$

With the help of interpolation to determine $\sigma_{pp\to n\text{ prong}}$, we present a test of eq.(7) in Table II and find this prediction reasonably successful. Note that, as the incident momentum doubles, both sides of eq.7 drop by a factor of 2 for n=4 and stay constant for n=6.

Eq.(8) allows the usual Mueller Regge behavior arguments to be advanced. In the central or double Regge region we expect the major contribution from double $(\omega+\rho)$ exchange (see Fig.IVa), as opposed to the double Pomeron exchange dominant in the total cross section. However

$$\frac{1}{\sigma_{(\bar{p}p)_A}} \left.\frac{d\sigma}{dy}\right|_{(\bar{p}p)_A}$$

should exhibit a central plateau constant as both rapidity, y, and energy, s, vary. The pion multiplicity in annihilation will grow like g^2 logs where g^2 now measures the $(\omega+\rho)-\pi-\pi-(\omega+\rho)$ double Regge coupling.

In the fragmentation regions, $(\omega+\rho)$ exchange again dominates (see Fig.IVb) and we expect Feynman scaling of

$$f'_{(\bar{p}p)_A} \equiv \frac{1}{\sigma_{(\bar{p}p)_A}} \left.\frac{d\sigma}{d^3p}\right|_{(\bar{p}p)_A} \qquad (9)$$

Note that this definition of f' differs from the usual one[5] in that it is normalized by the annihilation cross section. Similarly, the familiar results for two particle inclusive cross sections and triple Regge limits can be extended to the annihilation channel. An immediate result of our analysis is the prediction that the exchange degenerate secondary trajectories should have large triple Regge couplings only to baryon or strange meson trajectory pairs.

Thus the entire inclusive analysis program can be carried over to the annihilation program, under the reasonable assumptions that lead to the successful eqs.(6) and (7).

It is worth a brief mention that exactly analogous arguments can be applied to the K^-p and K^+p cross section difference leading to

$$\sigma_{K^-p} - \sigma_{K^+p} = \sigma_{K^-p \to Y \text{ + non-strange particles}} \quad (11)$$

where Y denotes a Λ or a Σ. Here the problem of non-hypercharged resonances decaying into $N\bar{K}$ pairs is a more serious one; and, experimentally, the hypercharge annihilation cross section is less than the cross section difference at 10(GeV/c) (3.2 mb to 5.2 mb)[10]. However, it is interesting that the hypercharge annihilation cross section does seem to fall[11] like $s^{-.5}$, as we would expect from eq.(11). Furthermore, scaling has been experimentally verified for f' (eq.9) for Λ production in this channel[11].

III A SIMPLE MULTIPERIPHERAL MODEL

In this section we develop and compare to the existing experimental data a multiperipheral model for baryon number annihilation. Strictly speaking, we investigate only annihilation into pions. However strange mesons are known to occur rarely (about 5% of the time at rest) and, in comparison to experimental data, we will ignore their existence.

The model used, described in detail in reference 12, assumes single pion production at each vertex of an iterated t channel exchange. An exponential damping, e^{At}, is assumed for the squared propagator of each t channel exchange. The partial cross section for annihilation into (n+2) pions, ignoring for the moment charge and interference terms, is then

$$\sigma_n = C g^{2n} (\sqrt{s}\ \ p_3)^{-1} \int d\Phi_{n+2} \exp\left\{A \sum_{i=1}^{n+1} t_i\right\} \tag{12}$$

where C is an overall normalization corresponding to the couplings at the end of the multiperipheral chain, and g^2 is the coupling constant for the emission of a pion off the baryon exchange. Here p_3 is the center of mass three momentum and $d\Phi_{n+2}$ is the usual (n+2) elemental phase space. For application to annihilation we fix A at the value 1.7 $(\text{GeV/c})^{-2}$ formerly found appropriate to describe pion production in the total cross section[12]. For simplicity we assume only nucleon exchange along the multiperipheral chain. This assumption is in part justified by the known weakness of the decuplet coupling at the ends of the chain (as evidenced by the small backward $\pi^- p$ differential cross section). Then C and g^2 are numbers, not matrices; and we can determine their values from non-annihilation data via eq.6. g^2 is set to approximately reproduce the $s^{-.5}$ energy dependence of the left hand side of eq.6 (over the incident momentum range of 3 to 10.(GeV/c)); and the overall normalization C is set accordingly. We thus arrive at a no free parameter model for the complete annihilation process. No approximations are made in calculation. Interference terms, between multiperipheral diagrams with the same final states produced in different orders along the chain, are important[13] and are explicitly included in the calculation (with the Regge signature factor assumed for the phase of each exchange).

It is obvious that there is physics that this simple model does not contain, e.g., resonance formation. However, as we see below, although it does often fail to correctly predict specific final state cross sections, its overall description of the grosser aspects of annihilation is excellent.

In Fig.V we compare the predicted charged pion multiplicity to the experimental data.[14,15,16,17] The no-parameter prediction is good to 10% in magnitude and even better in energy dependence. In Fig.VI we compare our predictions for σ_n, the cross section for annihilation into n charged prongs, to experimental data.[18,24] Again the agreement with experiment is excellent. It is interesting to note that the predicted σ_n distribution for annihilation is, in agreement with experiment, narrower than a Poisson distribution and shows no sign of widening with increasing energy. The success of the multiperipheral model here is in contrast to its failure (too narrow a σ_n distribution) to correctly predict σ_n for total cross sections.[12]

In Table III and IV we compare to experimental data[16,25] our predictions for the branching ratios into pions of $\bar{p}p$ and $\bar{p}n$ annihilations at rest. Here too experimental agreement is good, although the tendency to underestimate the charged pion multiplicity (discussed below) is now more serious. As is evident in Table II specific final states are often badly estimated. This is probably a result of the absence of resonance production in our model, e.g., the authors of reference 16 estimate that 100% of the $2(\pi^+\pi^-)$ state (which we badly underestimate) is $\rho\pi\pi$. In calculating Tables III and IV no assumptions as to s state annihilation or special conservation laws are made; in any case these questions have little effect on the charged prong branching ratios.

An especially interesting aspect of Table I is the prediction that

$$\langle n_{\pi^+} \rangle = \langle n_{\pi^-} \rangle < \langle n_{\pi^0} \rangle \qquad (12)$$

This enhancement of π^0 production over the statistical expectation persists at higher energies and is a direct result of the inclusion of interference terms and the assumption of dominant nucleon exchange. Most interference terms are in phase and, with many π^0s in the final state, more of them are allowed (with many π^+s and π^-s is the final state they are often forbidden by charge conservation). The introduction of Δ exchange would reduce, but probably not eliminate, this enhancement. Experimentally, the π^0 multiplicity can be approximately determined if the average π^0 energy is assumed equal to the average charged π energy (an assumption that is approximately true in our model calculations). Unfortunately, we know of no such determination more recent than that of Chamberlain et al[26] who does indeed, though with low statistics, observe just such an effect.

There are no experimental measurements of the inclusive single π distributions in annihilation so we confine ourselves to a brief description of our model predictions. A flat and fairly wide rapidity distribution develops quickly (a width of 1. at $p_{lab} = 10(GeV/c)$). The average transverse momentum of charged pions increases slowly from 250 MeV/c just above at rest to 320 MeV/c at an incident momentum of 10(GeV/c). At this energy the average center of mass three momentum of charged pions is 605(MeV/c), thus

$$<|\vec{p}|> \; > \; \sqrt{1.5} < p > \qquad (13)$$

where equality is expected for equidistribution of the available energy, as, for example, in a statistical model.

In Table V we compare our prediction of limited transverse momentum to the experimental data, which exist only for specific final states. Again the theoretical predictions are in reasonable agreement with experiment, although a slightly smaller value of A would provide even better agreement. Note that all these experimental data satisfy eq.(13) and contradict the naive statistical model's prediction of unlimited transverse momentum.

In summary of this section, we have demonstrated that a simple multiperipheral model, consistent with the sum rules of Section II, provides a remarkably good no-parameter description of the annihilation process. In particular we have shown that there is no experimental data contradicting the multiperipheral picture of annihilation, while the small average transverse momenta of Table IV are evidence against a statistical model at energies above at rest.

IV SUMMARY

The purpose of this paper has been to emphasize the importance of baryon number annihilation as a test of models of particle production. In Sections II and III we have presented a description of the annihilation cross section from the standpoints of, respectively, a general and specific multiperipheral model. In both Sections, the comparisons of predictions with experimental data have been consistently successful and more impressive than the model's record in describing total cross sections. This last fact is a confirmation of our emphasis on annihilation as a testing ground for specific models. While there were no free parameters available in our analysis of Section III, a similar complete analysis of the total cross section would require many.

Further experimental investigation of the annihilation process would provide immediate tests of the many sum rules derived in Section II and of the specific model of Section III. The measurement of single particle inclusive distributions would be particularly interesting. In principle, these single particle spectra could be quite different from those of the total cross section. However, our results in Section III, where the same exponential damping, A, for each momentum transfer is shown successful for annihilation and total cross sections, indicate, prosaically, similar production systematics for annihilation and total cross sections.

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TABLE I

Comparison of $(\sigma_{\bar{p}p} - \sigma_{pp})$ to $\sigma_{(\bar{p}p)_A}$ and $\sigma_{\bar{p}p\to 0\ \text{prongs}}$ [(a)]

All cross sections are in mb.

p_{lab}	$\sigma_{\bar{p}p} - \sigma_{pp}$	$\sigma_{(\bar{p}p)_A}$	$\sigma_{\bar{p}p\to 0\ \text{prongs}}$
.6 (GeV/c)	129.4±5.	81.1±2.9	16.4±1.3
1.61	48.5±4.	51. ±3.	
5.7	22.8±1.4	22. ±2.	3.3
6.94	15.4±3.	25 ±5.[(b)]	1.4± .3

a) Data, except where otherwise noted, from reference 18.

b) Reference 24

TABLE II

Comparison of ($\sigma_{\bar{p}p\to n\ prongs}$ - $\sigma_{pp\to n\ prongs}$) to $\sigma_{(\bar{p}p)_A \to n\ prongs}$. All cross sections are in mb.[(a)]

	n	($\sigma_{\bar{p}p\to n\ pr.}$ - $\sigma_{pp\to n\ pr.}$)	$\sigma_{(\bar{p}p)_A\to n\ pr.}$
p_{lab} = 3.28 (GeV/c)			
	4	18.7±2.	17.3±1.2[(b)]
	6	6.5±1.	6.0± .5[(b)]
p_{lab} = 6.94 (GeV/c)			
	2	4.2± .4	5. ±2. [(c)]
	4	7.6±2.	10.3±2. [(c)]
	6	5.9±2.	7. ±1. [(c)]

(a) Data, except where otherwise indicated, from reference 18.

(b) Reference 20.

(c) Reference 19.

TABLE III

Experimental relative branching ratios, for $\bar{p}p$ into pions at rest, compared to theoretical predictions.

Channel	Experiment [a]	Theory
0 prong	3.5±0.5	2.8
2 prongs	44.7±1.2	56.5
$\pi^+\pi^-$	.34±.03	—
$\pi^+\pi^-\pi^o$	8.2±0.9	1.0
4prongs	48.0±1.1	40.0
$2(\pi^+\pi^-)$	6.1±0.3	1.7
$2(\pi^+\pi^-)\pi^o$	19.6±0.9	12.0
6 prongs	4.0±0.2	2.6
$3(\pi^+\pi^-)$	2.0±0.2	.6
$3(\pi^+\pi^-)\pi^o$	1.7±0.3	1.6
$\langle n_{ch} \rangle$	3.05±.04	2.80
$\langle n_\pi \rangle$		5.40

a) Data from reference 16.

TABLE IV

Experimental relative branching ratios, for $\bar{p}n$ into pions at rest, compared to theoretical predictions.

Channel	Experiment[a]	Theory
1 prong	16.4±0.5	35.4
3 prongs	59.7±1.2	49.0
$2\pi^-\pi^+$	2.3±0.3 (b)	0.3
$2\pi^-\pi^+\pi^0$	13.7±2.0 (b)	12.0
5 prongs	23.4±0.7	15.0
$3\pi^-2\pi^+$	4.2± .23 (b)	4.1
$3\pi^-2\pi^+\pi^0$	6.93±.36 (b)	6.5
7 prongs	.39±.07	.4
$\langle n_{ch} \rangle$	3.15±.03	2.61

a) Data, except where otherwise noted, from reference 25.

b) Reference 8.

TABLE V

Measured average transverse momentum for charged pions (in specific final states) compared to theoretical prediction.

Channel	Lab. mom.	Experiment	Theory
$3(\pi^+\pi^-)$	6.94	.397±.009[a]	.371
$3(\pi^+\pi^-)\pi^0$	6.94	.363±.003[a]	.336
$3(\pi^+\pi^-)m(\pi^0), m\geq 2$	6.94	.310±.002[a]	.246
$4(\pi^+\pi^-)$	5.7	.305 [b]	.312
	6.94	.339±.008[c]	.369
$4(\pi^+\pi^-)\pi^0$	5.7	.260 [b]	.242
	6.94	.297±.004[c]	.249
$4(\pi^+\pi^-)m(\pi^0), m\geq 2$	6.94	.246±.003[c]	.204
$5(\pi^+\pi^-)$	6.94	.246±.020[c]	.204
$5(\pi^+\pi^-)\pi^0$	6.94	.228±.010[c]	.209
$5(\pi^+\pi^-)m(\pi^0), m\geq 2$	6.94	.205±.008[c]	.193

a) Data from reference 21.

b) Data from reference 27.

c) Data from reference 23.

CAPTIONS:

Fig. I

Two descriptions of inclusive exchange of a trajectory R: (a) the disassociative model and (b) the multiperipheral model.

Fig. II

Inclusive exchange diagrams for (a) the baryon number annihilation, (b) the hypercharge annihilation, and (c) the pp total cross section amplitudes. B denotes a baryon exchange, M a meson (secondary trajectory) exchange, P a Pomeron exchange, K a strange meson exchange.

Fig. III

a) Contributions of type 1 (see text) to the $\bar{n}n$ and nn total cross sections. Here the +(-) sign holds if the pair (MM') is even (odd) under charge conjugation.

b) The baryon number annihilation contribution to the $\bar{n}n$ cross section.

c) Baryon number annihilation contributions to $\sigma_{\bar{n}n}$ that would not be counted in $\sigma^{exp.}_{(\bar{n}n)_A}$. Here D denotes an $\bar{N}N$ meson resonance.

Fig. IV

Mueller Regge diagrams for $(\bar{p}p)_A$ inclusive distributions in (a) the central region and (b) the proton fragmentation region.

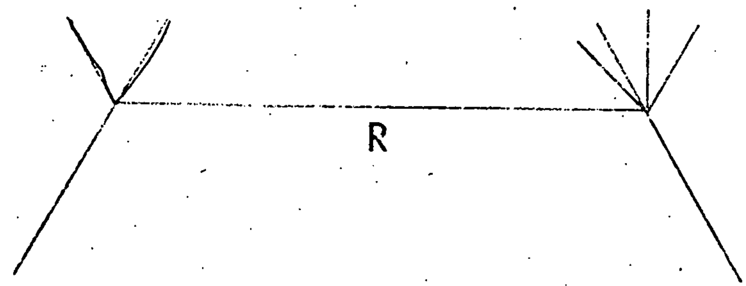
Fig. V

The measured average charged pion multiplicity, $\langle n_{ch} \rangle$, in annihilation processes (as a function of incident momentum) compared to the no free parameter theoretical prediction (solid line).

Fig. VI

The measured cross sections σ_n for $(\bar{p}p)_A$ into n charged prongs compared to the no free parameter theoretical prediction.

a



b

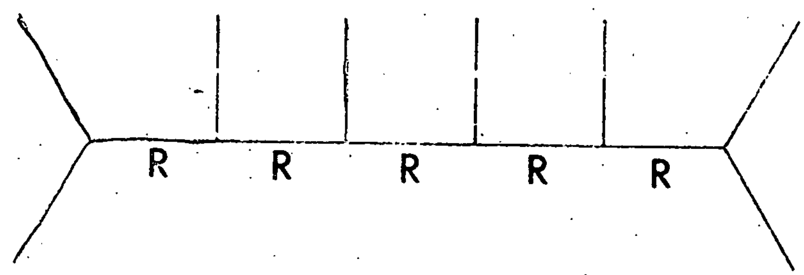


Fig. I

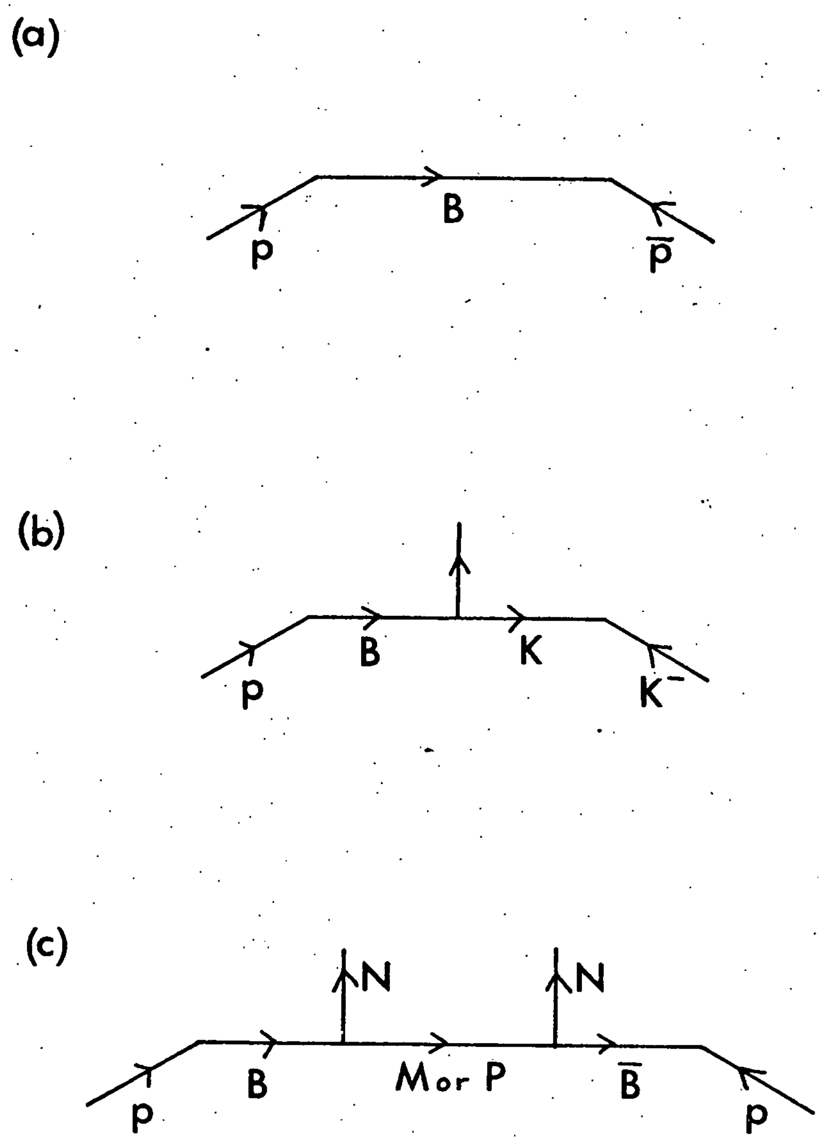
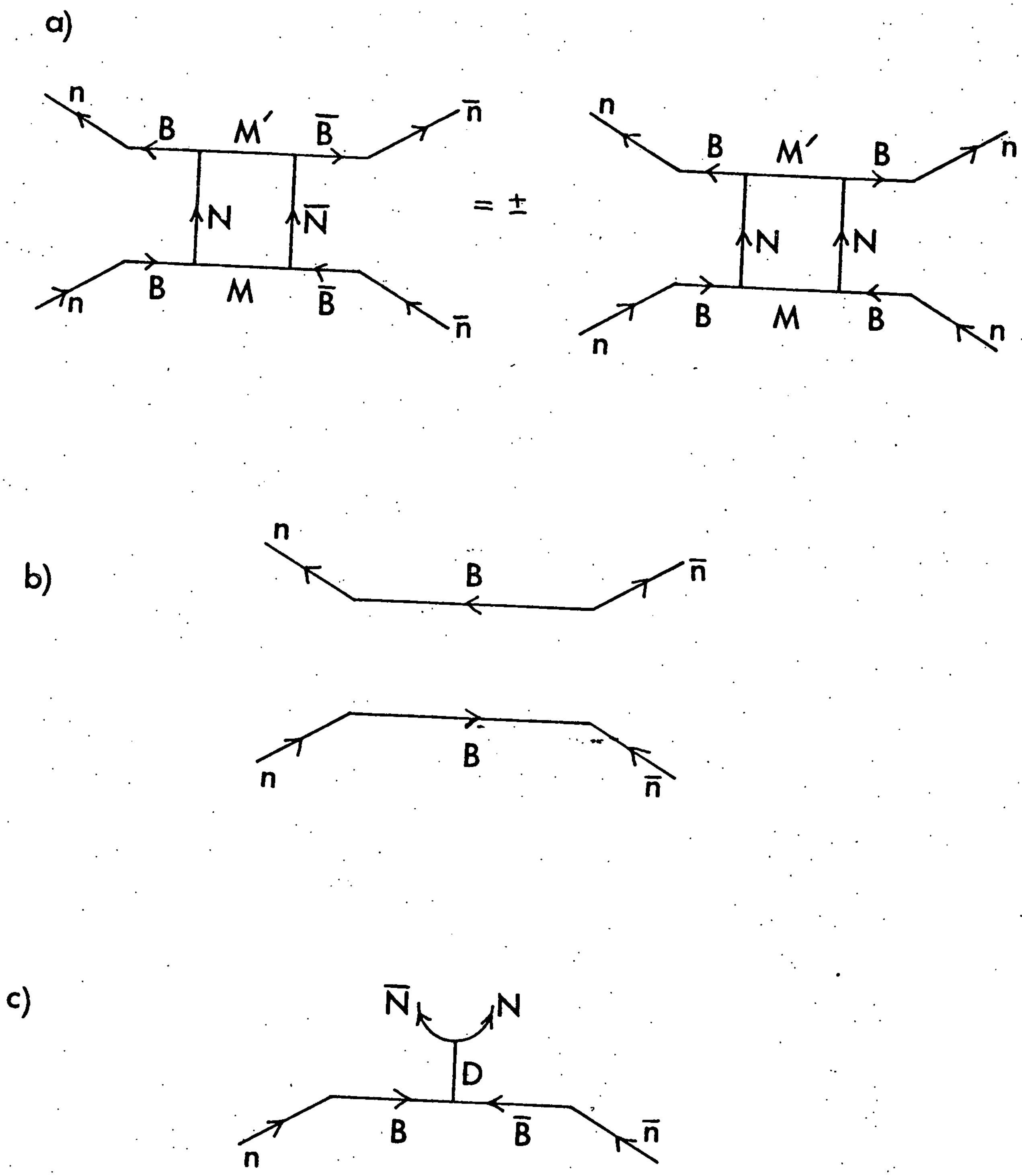


Fig. 11


a)
n
B
M′
$\bar{B}$
$\bar{n}$
N
$\bar{N}$
= ±
B
M
$\bar{B}$
$\bar{n}$
n
B
M′
B
n
N
N
B
M
B
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b)
n
B
$\bar{n}$
B
n
$\bar{n}$
c)
$\bar{N}$
N
D
B
$\bar{B}$
n
$\bar{n}$

Fig. III

a)

b)

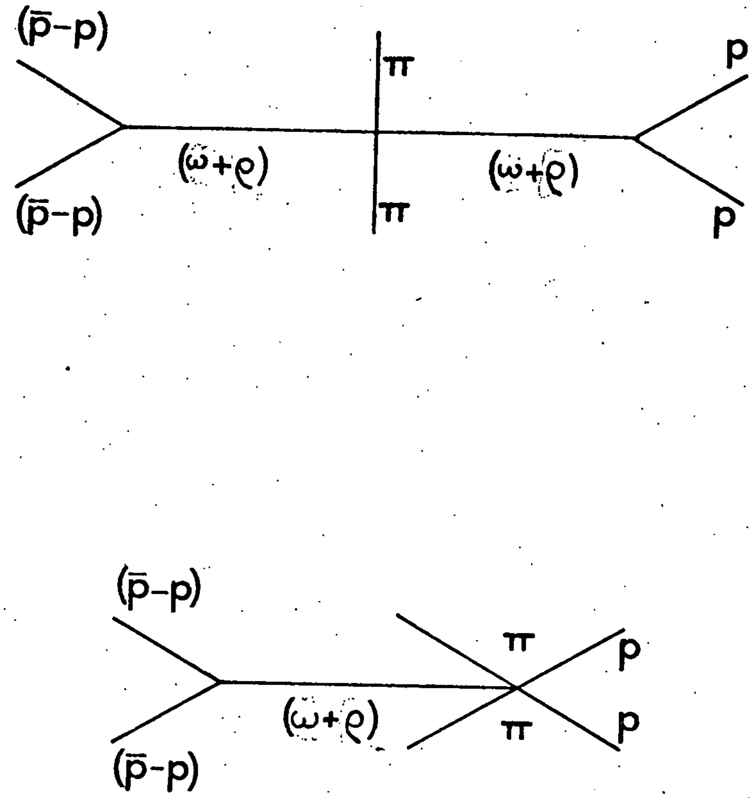


Fig. IV

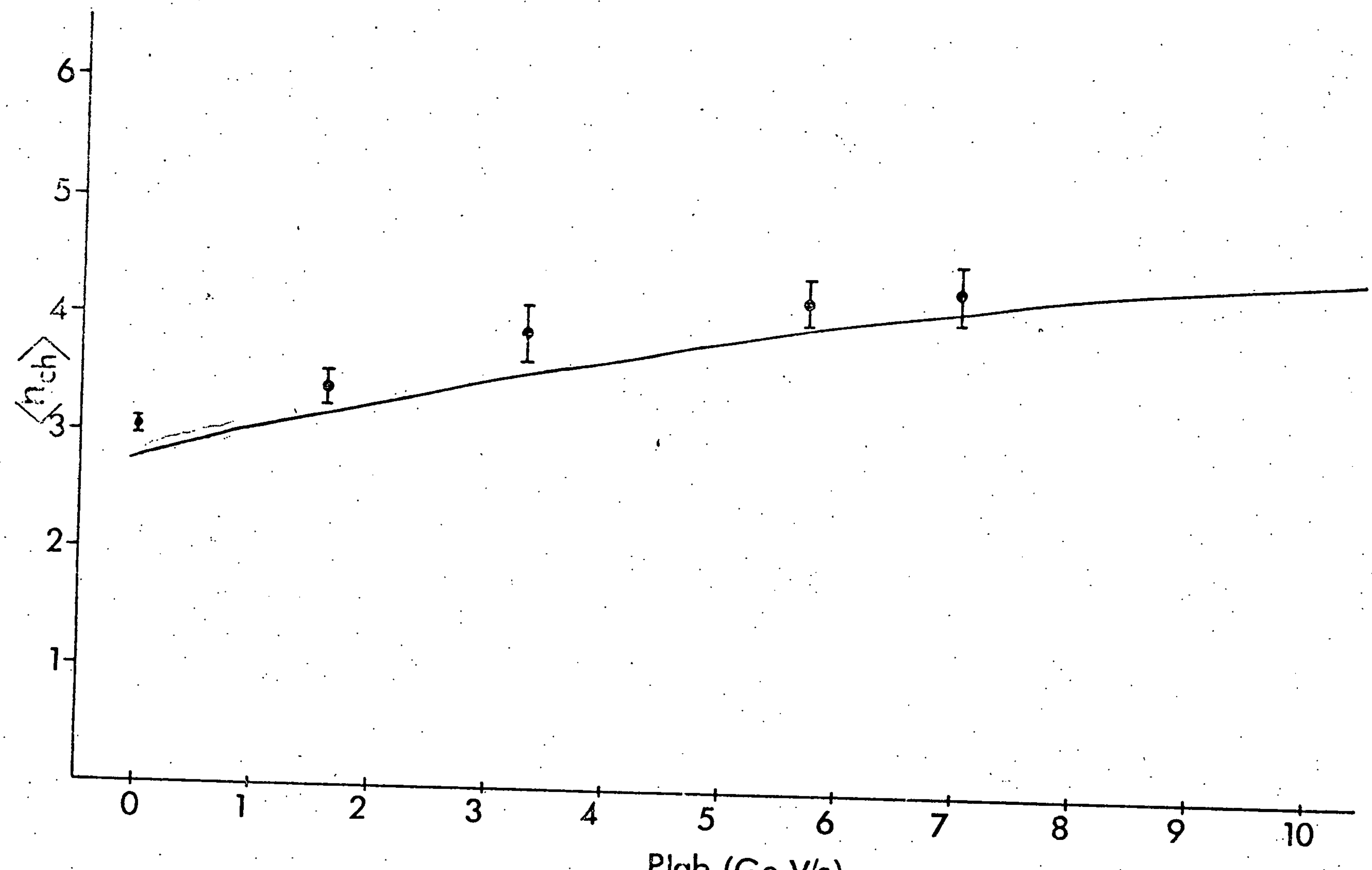
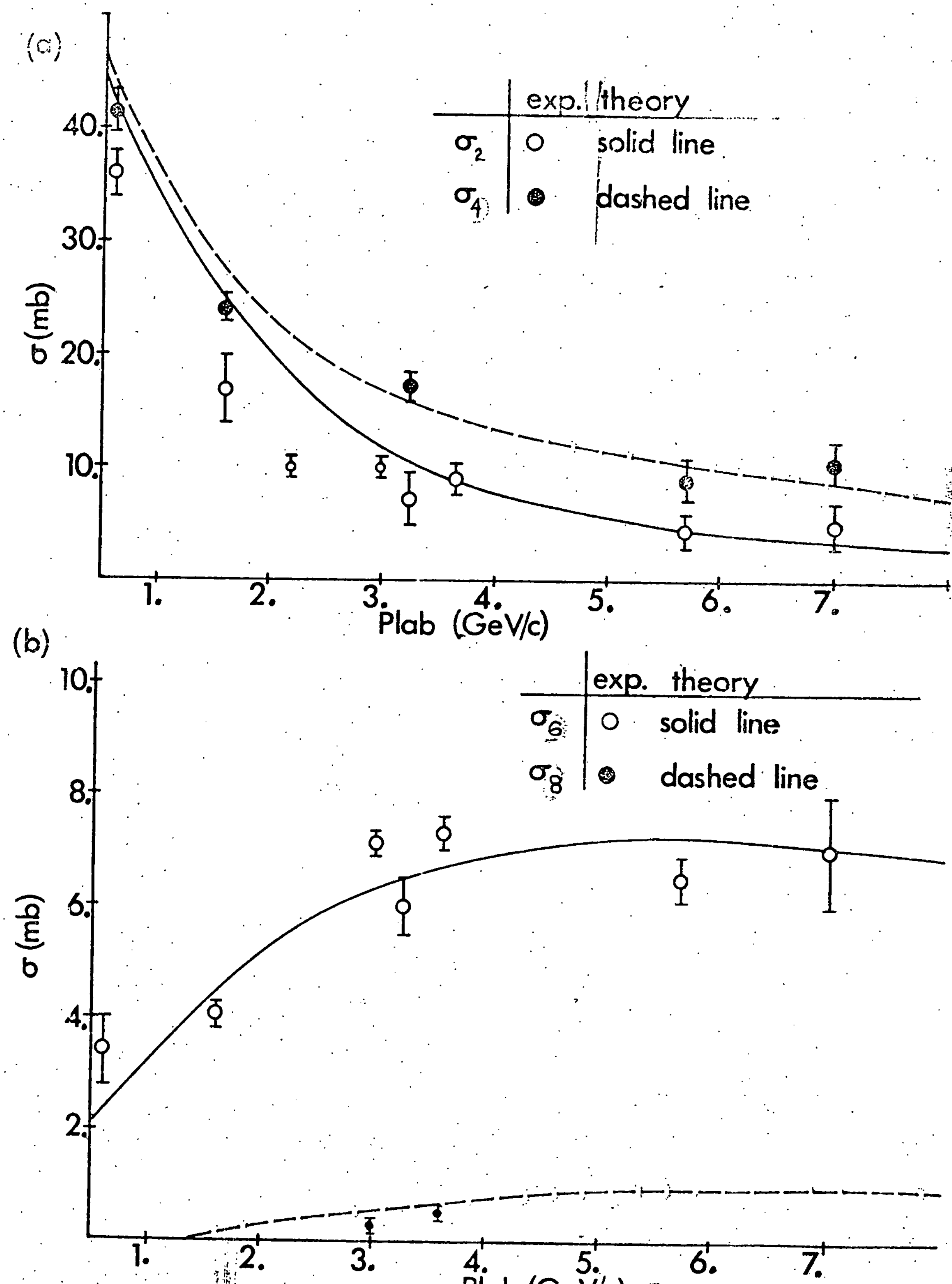


Fig. V



(a)
exp. theory
σ2 ○ solid line
σ4 ● dashed line
40.
30.
20.
10.
σ (mb)
1. 2. 3. 4. 5. 6. 7.
Plab (GeV/c)
(b)
exp. theory
σ6 ○ solid line
σ8 ● dashed line
10.
8.
6.
4.
2.
σ (mb)
1. 2. 3. 4. 5. 6. 7.
Plab (GeV/c)

Fig. VI