Interrelation between Exclusive and Inclusive Reactions

—Inclusive Reactions and Urbaryon Rearrangement Diagrams. II—

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(Received March 4, 1972)

The interrelation between exclusive and inclusive reactions is investigated from the standpoint of the urbaryon rearrangement diagram. A reduction rule of urbaryon lines is proposed to analyse the unitarity relation between exclusive and inclusive reactions. The selection rule for urbaryon rearrangement diagrams to characterize the forward absorptive amplitude, which contributes to the N-particle inclusive spectrum through the generalized optical theorem, is derived from the reduction rule. The total cross section and single-particle distribution are discussed in detail. Our approach does not rest on the Harari-Freund hypothesis nor suffer from the baryon problem in duality.

§ 1. Introduction

Recently, attempts to clarify the structure of high energy hadron-hadron interaction have been tried from various viewpoints. In particular, many theorists and experimentalists have payed much attention to the structure of inclusive reactions. However, the structure of inclusive reactions must be considered in connection with the one of exclusive reactions. In fact inclusive spectra (total cross section, single-particle distribution, etc.) are described by the following two formulations: the first formulation is the sum over multiplicity and channel $n$ of exclusive spectra in the exclusive reaction $2 \to n$, and the second formulation is the discontinuity of the forward elastic amplitude by the generalized optical theorem. The two formulations are related by unitarity and analyticity. It is an important problem to clarify the interrelation between the first formulation and the second one, since the unitarity relation among reaction amplitudes is an important clue to understand the structure of hadrodynamics at high energies.

On the other hand, in the first paper*) 1) we investigated the production mechanism of the single-particle distribution from the standpoint of urbaryon rearrangement diagram (abbreviated to URD) combined with the second formulation. There we considered mainly the five types of URD such as shown in Fig. 1 to explain the essential features of the experiments, especially the shapes of the momentum spectra. However, it remains open to question whether or not the other type URD amplitude contributes to the discontinuity of the forward $(N+2)$-

*) Reference 1) is referred to as I. References cited in I are mostly omitted in this paper.
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body scattering amplitude in the
N-particle distribution of the
inclusive reaction $a + b \rightarrow 1 + 2 + \cdots + N + \text{anything}$. The above
problem is closely related to
the problem of duality in the
$BB$ and $B\bar{B}$ channels, where
$B$ denotes the baryon.

In this paper we investigate
the unitarity relation,
which combines the first formu­
lation with the second one,
from the standpoint of URD.
We propose the reduction rule
of urbaryon lines. Then all
the contributions specified by URD for exclusive reactions are classified into a
few groups by the characters of the urbaryon line flow and it connects each
URD group of exclusive reactions with a certain type of URD for inclusive
reactions. By the reduction rule, we clarify the interrelation between exclusive and inclusive reactions. Also, we clarify what types of URD contribute generally to the discontinuity of the $(N+2)$-body forward amplitude in the $N$-particle
distribution.

Our approach may provide a starting basis for the combined studies of ex­
clusive and inclusive reactions, towards deeper understanding of hadron interactions. It should be noted that our basic view is to study these problems on the basis of the structure of exclusive reactions in terms of urbaryon line flow.

In §2 we discuss the reduction rule of urbaryon lines. In §§3 and 4 we discuss the total cross section ($N=0$) and single-particle distribution ($N=1$) on the basis of the reduction rule, respectively. In §5 a discussion is given.

§2. Reduction rule of urbaryon lines

We consider the inclusive reaction $a + b \rightarrow 1 + 2 + \cdots + N + \text{anything (X)}$. In
the first formulation we can represent the $N$-particle distribution as a sum over
the multiplicity and channel $n$ of the spectrum of exclusive reaction $a + b \rightarrow 1 + 2 + \cdots + N + \cdots + n$ (referred to as the unitarity sum) as follows:

$$\frac{d^N \sigma}{\prod_{i=1}^{N} (dq_i / \omega_i)} = \frac{1}{s} \sum_n |T_{ab}^{12-N-n}|^2,$$

where $T_{ab}^{12-N-n}$ denotes the $n$-particle production amplitude and the sum over $n$
denotes the sum over multiplicity and channel and the integration over allowed
phase-space for the particles $N+1, N+2, \cdots, n$. Also $q_i$ and $\omega_i$ are the three-
momentum and the energy of the $i$-th produced particle respectively, and $s$ is the total energy squared.

In the second formulation, by unitarity and analyticity we can obtain the following generalized optical theorem from Eq. (1):

$$\frac{d^N \sigma}{\prod_{i=1}^{N} (d q_i / \omega_i)} = \frac{1}{s} \text{disc} T^{a_1 \cdots N_b}_{a_1 \cdots N_b},$$

(2)

where $T^{a_1 \cdots N_b}_{a_1 \cdots N_b}$ denotes the forward elastic scattering amplitude of $a + 1 + \cdots + N + b \rightarrow a + 1 + \cdots + N + b$ in the physical region of inclusive reaction $a + b \rightarrow 1 + 2 + \cdots + N + X$. We may illustrate the above relation in Fig. 2.

Fig. 2. The illustration of the unitarity relation.

We consider that hadrodynamics is prescribed by the urbaryon line flow mapped on URD,*) and expand the amplitudes $T^{a_1 \cdots N}_{a_1 \cdots N}$ and $T^{a_1 \cdots N_b}_{a_1 \cdots N_b}$ in terms of various types of URD amplitudes corresponding to various types of URD as follows:

$$T^{a_1 \cdots N}_{a_1 \cdots N} = \sum_{\alpha} U^{a_1 \cdots N}_{\alpha},$$

(3)

where $U^{a_1 \cdots N}_{\alpha}$ denotes an $\alpha$-type URD amplitude for the exclusive reaction $a + b \rightarrow 1 + 2 + \cdots + N + \cdots + n$, and

$$T^{a_1 \cdots N}_{a_1 \cdots N} = \sum_{\beta} F^{a_1 \cdots N}_{\beta},$$

(4)

where $F^{a_1 \cdots N}_{\beta}$ denotes a $\beta$-type URD amplitude of the $(N+2)$-body forward elastic scattering amplitude.

From Eqs. (1), (2), (3) and (4), we obtain

$$\sum_{\alpha} |\sum_{a} U^{a_1 \cdots N}_{\alpha}|^2 = \sum_{\beta} \text{disc} F^{a_1 \cdots N}_{\beta}.$$

That is,

$$\sum_{a} \sum_{a'} (\sum_{\alpha} U^{a_1 \cdots N}_{\alpha} U^{a_2 \cdots N-a}_{\alpha}) = \sum_{\beta} \text{disc} F^{a_1 \cdots N}_{\beta}.$$

(5)

Now we investigate the interrelation between the terms on the left- and right-hand sides in Eq. (5), by two steps. As the first step, we introduce the following reduction procedure of urbaryon lines.

An URD, which characterizes the product of the $\alpha$- and $\alpha'$-type amplitudes

*) Here, we do not bother about the problem of statistics of urbaryons in the URD amplitudes.
with the unitarity sum of the complicated intermediate states \( n \) in the left-hand side of Eq. (5), can be reduced into a simple URD which corresponds to the URD for characterizing the \((N+2)\)-body forward amplitude, by the following operations:

1. eliminate the closed loops in the intermediate states,
2. straighten the winding lines connecting initial and final states without altering the topology.

We can reduce all the URDs on the left-hand side of Eq. (5) to those on the right-hand side of Eq. (5) topologically by the above operations. Then we propose the following identification:

\[
\sum_\alpha \sum_\alpha' (\sum_n U_{\alpha}^{112-\ldots-N-\ldots-\alpha} U_{\alpha'}^{112-\ldots-N-\ldots-\alpha} ) = \text{disc } \mathcal{F}_{(\delta)}^{\alpha_{1}\ldots\alpha_{N} \beta},
\]

where \( \alpha \) and \( \alpha' \) denote the type of URD, which is reduced to the \( \delta \)-type URD by the above operations. Equation (6) implies that the amplitude on the right-hand side, characterized by an irreducible URD, represents the sum of all the contributions from the processes characterized by possible reducible diagrams.

As a second step, we discuss the approximation for the sum over \( \alpha \) and \( \alpha' \) concerning the \( \alpha \)- and \( \alpha' \)-type URD amplitudes in Eq. (6). We can rewrite Eq. (6) by separating the diagonal elements and the off-diagonal elements concerning the suffices \( \alpha \) and \( \alpha' \) on the left-hand side of Eq. (6) as follows:

\[
\sum_\alpha (\sum_n |U_{\alpha}^{112-\ldots-N-\ldots-\alpha}|^2) + \sum_{\alpha \neq \alpha'} (\sum_n U_{\alpha}^{112-\ldots-N-\ldots-\alpha} U_{\alpha'}^{112-\ldots-N-\ldots-\alpha}) = \text{disc } \mathcal{F}_{(\delta)}^{\alpha_{1}\ldots\alpha_{N} \beta}.
\]

The sign of each term in the off-diagonal element sum is not definite. So, if we assume its randomness, we may expect cancellations among contributions of the same order of magnitude, while in the diagonal element sum, each term adds up coherently with positive sign. Therefore we adopt the following approximation:  
\( ^* \) on the left-hand side of Eq. (7) the diagonal element sum is dominant, and the off-diagonal element sum is nearly zero as a first approximation.

This approximation suggests that the URD amplitude \( \mathcal{F}_{(\delta)}^{\alpha_{1}\ldots\alpha_{N} \beta} \), which relates to the unitarity sum of the diagonal elements, contributes to the discontinuity of the forward \((N+2)\)-body amplitude, but the URD amplitude \( \mathcal{G}_{(\delta')}^{\alpha_{1}\ldots\alpha_{N} \beta} \), which relates only to the unitarity sum of the off-diagonal elements, does not. Thus we obtain

\[
\sum_\alpha (\sum_n |U_{\alpha}^{112-\ldots-N-\ldots-\alpha}|^2) + \cdots = \text{disc } \mathcal{F}_{(\delta)}^{\alpha_{1}\ldots\alpha_{N} \beta} \neq 0,
\]

\[
\sum_{\alpha \neq \alpha'} (\sum_n U_{\alpha}^{112-\ldots-N-\ldots-\alpha} U_{\alpha'}^{112-\ldots-N-\ldots-\alpha}) = \text{disc } \mathcal{G}_{(\delta')}^{\alpha_{1}\ldots\alpha_{N} \beta} = 0.
\]

We shall call the method of deducing Eq. (8), the reduction rule of \textit{urbaryon}

\( ^* \) Similar consideration was done in multichannel approach to high energy reactions in the name of \textit{random phase approximation}.  

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The reduction rule consists of the reduction procedures (1) and (2), and of the above approximation of retaining only the diagonal element sum concerning the unitarity relation.

In the following sections we apply the reduction rule to the total cross section \((N=0)\) and single-particle distribution \((N=1)\), and discuss the consequences of our proposal.

§ 3. Total cross section

In this section we discuss the consequences of the reduction rule for the inclusive reaction \(a+b\rightarrow\text{anything} \,(N=0)\). Our discussion starts from the structure of exclusive reactions from the standpoint of URD. We treat the \(n\)-particle production process

\[
a+b\rightarrow 1+2+\cdots+n,
\]

according to the basic pattern of the urbaryon line flow from the initial state into the final state. We can classify the types of URD into three groups as follows:*)

- **\(\bar{D}\)-type group**: Disconnected diagrams subject to the Iizuka-Okubo rule between particles \(a\) and \(b\),
- **\(\bar{H}\)-type group**: Connected diagrams in which at least one pair of urbaryons in \(a\) and \(b\) annihilates in the collision,
- **\(\bar{X}\)-type group**: Connected diagrams in which neither pair of urbaryon lines in \(a\) and \(b\) annihilates.

Here the three types \(\bar{D}\), \(\bar{H}\) and \(\bar{X}\) are called after the \(D\)-, \(H\)-and \(X\)-types which are effective in the two-body and quasi-two-body processes. The \(Z\)-type in the latter and similar ones in multi-particle production processes are classified into the \(\bar{H}\)-type in the above consideration. Typical examples are given in Fig. 3. Also, the types \(D\), \(H\), \(X\) and \(Z\) for meson-baryon scattering are shown in Fig. 4 for comparison.

![Fig. 3. Typical examples of \(\bar{D}\)-, \(\bar{X}\)- and \(\bar{H}\)-types of URD which characterize exclusive reactions.](https://example.com/fig3.png)

*) Previously, A. Kobayashi et al.\(^4\) considered various types of URD for exclusive reactions in studying the energy dependence of partial cross section. However, their terminology seems rather cumbersome for our purpose.
Fig. 4. The URDs which characterize two-body and quasi-two-body reactions.

From the above consideration, we obtain the following relations:

\[ T_{ab}^{12-n} = \sum_D U_D^{12-n} + \sum_H U_H^{12-n} + \sum_X U_X^{12-n} \quad (9) \]

and

\[ \sum_n |T_{ab}^{12-n}|^2 = \sum_D (\sum_n |U_D^{12-n}|^2) + \sum_H (\sum_n |U_H^{12-n}|^2) + \sum_X (\sum_n |U_X^{12-n}|^2) \]
\[ + \sum_D \sum_H (\sum_n U_D^{12-n} U_H^{12-n}) + \sum_D \sum_X (\sum_n U_D^{12-n} U_X^{12-n}) + \cdots \quad (10) \]

We apply the reduction rule to Eq. (10) and obtain the types of URD amplitude which contribute to the discontinuity of the two-body forward elastic scattering amplitude. Then we get the following results:

\[ \text{disc } F_{(D)}^{ab} = \left( \sum_h (\sum_n |U_H^{12-n}|^2) + \sum_X (\sum_n |U_X^{12-n}|^2) \right) \]
\[ \text{disc } F_{(H)}^{ab} = \sum_h (\sum_n |U_H^{12-n}|^2), \quad \text{disc } F_{(X)}^{ab} = 0. \quad (11) \]

We illustrate an example of the reduction procedure for the first term on the right-hand side of Eq. (10) in Fig. 5.

Fig. 5. The illustration of the reduction rule for the total cross section.

Thus, the \( D \)- and \( H \)-type URD amplitudes contribute to the discontinuity of the forward elastic amplitude in the physical region of \( a+b \rightarrow X \), while the \( X \)-type URD amplitude does not. This result is in good agreement with the phenomenological analyses of the two-body scattering in \( P_L \sim 2 \sim 20 \text{ GeV/c} \). That is, the diffraction is pure imaginary, \( \text{Im } F_{(D)}^{ab} \neq 0 \) and \( \text{Im } F_{(X)}^{ab} = 0 \). Conversely, the experimental fact that \( \text{Im } F_{(X)}^{ab} = 0 \) implies that the off-diagonal-element sum at the level
of the URD amplitude is nearly zero. This result supports our reduction rule.

In our scheme the diffraction amplitude (\(D\)-type) is composed of two components, i.e., \(D\)-type contributions and \(X\)-type ones. The diffractive amplitude is characterized by the flatness of total cross section, which is almost realized down to \(P_L \approx 1.5 \text{ GeV/c}\) for \(KN\) collision and \(2 \text{ GeV/c}\) for \(NN\). Certainly, the bulk of the flat total cross section in the few \(\text{GeV/c}\) region seems to be due to the partial cross sections belonging to the \(X\)-type reactions. However, the asymptotic energy dependence of the partial cross sections belonging to the \(X\)-type shows fall-off similar to that of the \(H\)-type, contrary to the very slow fall-off of the \(D\)-type. Therefore, the relative importance between the two components at high energies is a very interesting problem for future experiments. This problem is closely related to the energy dependence of the average multiplicity, which will be discussed elsewhere.

§ 4. Single-particle distribution

We discuss the inclusive reaction \(a+b \rightarrow c+X (N=1)\). The types of URD which we adopted in I are derived by the reduction rule. Therefore our rule seems to prescribe the important face of hadrodynamics.

When we treat the single-particle distribution, we must note the production mechanism of the produced particles, as emphasized in I. We distinguish the following three categories in each URD of exclusive reaction:

Category (I): All of the lines in \(c\) originate from all of the lines in either \(a\) or \(b\),

Category (II): Part of the lines in \(a\) and/or \(b\) flows into \(c\),

Category (III): None of the lines in \(a\) or \(b\) flows into \(c\). The particle \(c\) is made of urbaryon lines which are newly created in the collision.

These categories characterize the angular distribution and/or the longitudinal momentum distribution of the produced particle \(c\).

Considering the distribution of the production mechanism of the produced particle \(c\), we write the exclusive amplitude as follows:

\[
T_{ab}^{c_{23...n}} = \sum_\sigma \left\{ \sum_D U_{D,\sigma}^{c_{23...n}} + \sum_R U_{R,\sigma}^{c_{23...n}} + \sum_X U_{X,\sigma}^{c_{23...n}} \right\},
\]

(12)

where \(\sigma\) denotes the category of the production mechanism. Then, by the unitarity sum of the exclusive spectrum, we obtain

\[
\sum_n |T_{ab}^{c_{23...n}}|^2 = \sum_\sigma \left\{ \sum_D |U_{D,\sigma}^{c_{23...n}}|^2 + \sum_R |U_{R,\sigma}^{c_{23...n}}|^2 + \sum_X |U_{X,\sigma}^{c_{23...n}}|^2 \right\}

+ \sum_\sigma \sum_{\sigma'} \sum_D \sum_R (U_{D,\sigma}^{c_{23...n}} U_{R,\sigma'}^{c_{23...n}}) + \cdots \right\}.
\]

(13)

We apply the reduction rule to Eq. (13). We illustrate in Fig. 6 the typi-
A typical example of the reduction procedure for the mechanism which is characterized by the category (II) in the $\mathcal{D}$-type URD for meson + baryon $\rightarrow$ meson + anything.

In general, according to the reduction rule the single-particle distribution for $a(\text{meson}) + b(\text{baryon}) \rightarrow c(\text{meson}) + X$ can be described by the following relations:

\[
\text{disc } F^{ab}(D \otimes P, \text{Ia}) = \sum_n \left( \sum_D |U_{D,1a}^{\text{D}a}|^2 \right),
\]
\[
\text{disc } F^{ab}(D \otimes H, \text{Ia}) = \sum_n \left( \sum_D |U_{D,1a}^{\text{D}b}|^2 \right),
\]
\[
\text{disc } F^{ab}(H \otimes P, \text{IIa}) = \sum_D \left( \sum_n |U_{D,1a}^{\text{II}a}|^2 \right) + \sum_X \left( \sum_n |U_X^{\text{II}a}|^2 \right),
\]
\[
\text{disc } F^{ab}(H \otimes P, \text{IIb}) = \sum_D \left( \sum_n |U_{D,1b}^{\text{II}b}|^2 \right) + \sum_X \left( \sum_n |U_X^{\text{II}b}|^2 \right),
\]
\[
\text{disc } F^{ab}(H \otimes P, \text{III}) = \sum_R \left( \sum_n |U_{R,1b}^{\text{II}b}|^2 \right),
\]
\[
\text{disc } F^{ab}(P \otimes P, \text{III}) = \sum_D \left( \sum_n |U_{D,1a}^{\text{III}a}|^2 \right) + \sum_X \left( \sum_n |U_X^{\text{III}a}|^2 \right),
\]
\[
\text{disc } F^{ab}(H \otimes H, \text{IIa}) = \sum_X \left( \sum_n |U_{X,1a}^{\text{IIa}}| \right),
\]
\[
\text{disc } F^{ab}(H \otimes H, \text{IIb}) = \sum_R \left( \sum_n |U_{R,1b}^{\text{IIb}}| \right),
\]
\[
\text{disc } F^{ab}(H \otimes H, \text{III}) = \sum_R \left( \sum_n |U_{R,1b}^{\text{III}b}| \right),
\]

where $B^*$ denotes the baryon resonance produced diffractively. We show the $H \otimes P$ and $H \otimes H$ type URDs of Eq. (14) in Fig. 7. We obtain the result that the contribution of the other URD amplitude to the discontinuity of the three-body forward scattering amplitude is nearly zero. It should be emphasized here that the URD with pairs of lines with single crossing similar to the $X$-type URD, such as shown in Fig. 8, does not contribute to the discontinuity of the three-body forward amplitude, because these diagrams are derived from the off-diagonal element. These consequences support the selection of the type of URD in I. Also our results seem to be quite consistent with the present experimental situation.

In our approach the problem of whether the single-particle distribution ex-
Fig. 7. The URDs of the $H\otimes P$ and $H\otimes H$ types derived by the reduction rule for the inclusive reaction Meson+Baryon$\rightarrow$Meson+anything.

Fig. 8. Typical examples of the URDs whose amplitudes do not contribute to the discontinuity of the three-body forward amplitude owing to the reduction rule.

habits scaling behaviour is related to the problem of what type of URD is dominant in exclusive reactions in which the particle $c$ is produced. That is, if the $D$-type URD is dominant in an exclusive reaction, the scaling behaviour for its reaction may be good. But if the $H$-type URD is dominant, the scaling behaviour should not be good. For example, let us consider the reaction $K^-p\rightarrow E^-X$. It seems experimentally that the $H$-type URD is more dominant than the $D$-type URD for this process in the energy range $P_L \approx 5 \sim 10$ GeV/c. Therefore in this case the scaling behaviour might be bad. The detailed discussion of the non-scaling part will be presented in a forthcoming paper.

Finally we should add a remark on the single-particle spectrum due to Category (I). As far as the topology of URD is concerned, the $D\otimes H$ type shown in Fig. 1 is not different from the $D\otimes P$ type. However, as was discussed previously in I, these two types should be distinguished due to quite different properties. The origin of the $D\otimes H$ type can be found in the diffractional resonance production such as $pp\rightarrow pN^*$ ($I=\frac{1}{2}$). While the effects of the non-diffractive resonance production such as $pp\rightarrow nA^{++}$, are contained in the $H\otimes H$ type URD by duality.

§ 5. Discussion

(1) We have discussed the reduction rule which clarifies the interrelation between exclusive and inclusive reactions. We applied it to the total cross section and single-particle distribution and obtained interesting consequences. Also, when we apply it to the two-particle distribution, our approach will be found very useful. Furthermore, our approach may provide a starting basis for the combined studies of exclusive and inclusive reactions for a deeper understanding of hadrodynamics.

(2) Previously, Ghoroku, Myozyo and one of the authors (H.N.Y) discussed the exotic problem of the $BB$ and $B\bar{B}$ reactions and introduced the exotic states. In our scheme, the $H$- and $H_a$-types of URD in the $B\bar{B}$ forward absorptive am-
plitude are introduced naturally. It is to be noted here that the $H$-type and $H_e$-type mechanisms are related to the reaction mechanism of $B\bar{B} \to B\bar{B}^+\bar{B}^-$ mesons and $B\bar{B} \to \bar{B}^+$ mesons, respectively. Also, the URD for the $a+\bar{z}+b \to a+z+b$ amplitude including baryons and/or antibaryons can be easily obtained through the reduction rule. This point is in marked contrast to the approach of Veneziano based on the Harari-Freund conjecture, although an interesting parallelism with ours may be found in the treatment of the $H$- and $P$-types for meson reactions. Another crucial difference between his work and ours is that he adopts the Freund model of the Pomeron. There, the $D$-type URD for exclusive reactions is absent, and it follows that the $D\otimes P$ type for the single-particle distribution is absent.

(3) In our approach, the urbaryon line is considered to reflect some aspects of the fundamental entity to constitute hadrons. In this respect, it is interesting to compare our model with the annihilation model by Henzi et al. as regards the difference between the particle and antiparticle total cross sections for a proton target. They consider that the difference is caused by the annihilation channels being open only to the antiparticles. In practice, they adopt the concept of charge, hypercharge and baryon number annihilations to explain the differences in $\pi^+p$, $K^+p$, $p^+p$ total cross sections, respectively. As they note themselves, charge annihilation is not well defined in connection with charge independence. The hypercharge annihilation processes such as $K^-+p\to\Lambda+p$ pions are not restricted to the $H$-type in our approach. Also, the hypercharge annihilation is not well defined with regard to unitary symmetry. On the other hand, the difference of the $p^+p$ total cross sections below 5 GeV/c is in qualitative agreement with their scheme. This result may be taken, in our approach, as the dominance of the $H_e$-type contribution over the $H$-type one. While, the energy dependence of the difference above $P_t \approx 10$ GeV/c up to 60 GeV/c is well described by the $s^{-1/2}$ behaviour, consistent with the $H$-type dominance. The $H_e$-type is expected to damp much faster, according to the $s^{-7/8}$ behaviour. The model of Henzi et al. may disagree with experiment in the region above 10 GeV/c. It is to be noted that the total cross section difference in our scheme is due to the $H$-type exclusive reactions characterized by the annihilation of urbaryon pairs in the initial states, while Henzi et al. define the annihilation channels without recourse to the urbaryons.

**Acknowledgements**

The authors would like to express their gratitude to Professor S. Otsuki, Professor M. Uehara and other members of their institute for valuable discussions and encouragement. One of the authors (H.N.) is also grateful for stimulating discussions to members of the research group "Multiparticle Productions" organized by the Research Institute for Fundamental Physics, Kyoto University, in 1971.
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References


Note added in proof:

1. Energy dependence of the particle multiplicities due to Categories II and III is discussed in connection with the early limiting behaviour of $H \otimes P$ (IIa or IIb) and the steep increase to the scaling limit for $P \otimes P$, in a subsequent paper “Production Rates and Distinctive Components of Single-Particle Distributions” [Prog. Theor. Phys. 48 (1972), No. 4].

2. If the dominant processes for exclusive reactions are known, we become able to select out the dominant diagrams for inclusive reactions, on the basis of the reduction rule discussed here. This point will be extensively discussed in “Rank Structure of Exclusive Reactions and Characteristic Features of Inclusive Spectra” (to appear in Prog. Theor. Phys. 48 (1972), No. 6 (b)).