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January 10, 1973

Prepared for the U.S. Atomic Energy
Commission under Contract W-7405-ENG-48

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FRAGMENTATION AND MULTIPERIPHERAL DYNAMICS: A CONNECTION THROUGH UNITARITY*

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January 10, 1973

ABSTRACT

A rapidity space decomposition of s-channel unitarity implies interdependence between production mechanisms. The presence of a low multiplicity diffractive production channel shadows the multiperipheral mechanism while the high multiplicity multiperipheral channel shadows the diffractive mechanism in the high produced mass region. The first effect results in negative contributions to the effective two-pomeron cut. Pomeron couplings to elastic and inelastic channels then require a cut structure which evades decoupling theorems. For hard cuts there is a connection between the relative amount of diffractive production and the dip in $d\sigma^{PP}_{e\ell}/dt$ at $-t = 1.2\ \mathrm{GeV}^2/c^2$ at ISR. The consequent cut to pole strength is 10-20%. It is conjectured that the situation described here resembles the approach to a phase transition in the multiperipheral gas.

* This work was supported by the U. S. Atomic Energy Commission.

The problem of the pomeron's role in inelastic reactions has occupied theorists since the work of Finkelstein and Kajantie [1] in which intercept one pomeron pole occurrences in a multi-Regge chain violate direct channel unitarity. Recent work has extended these results to inclusive reactions where the violation of unitarity perhaps more appropriately appears as a violation of energy conservation sum rules. It appears that a factorizable, intercept one, pomeron must decouple (at zero pomeron mass) from all inelastic channels [2], and, if the continuations of Brower and Weis [3] are correct, from elastic reactions. One alternative to decoupling is that the pomeron intercept be below one [4]. Another is lack of factorization. In the first case, σ_{tot} vanishes asymptotically. Lack of factorization is accompanied by nonscaling contributions in inclusive reactions and by a good deal of calculational inconvenience. Experimentally, it would seem that there is such a nonscaling contribution but that it is not dominant. As realized some time ago by Wilson [5], and more recently by those confronting experimental data [6], a combination of short range correlation and diffractive mechanisms may be necessary to agree with experiment. Such two-component descriptions are becoming increasingly useful but the relationship between the two mechanisms, particularly as a function of energy, is still an open question.

The way in which the two-component picture attains consistency with unitarity, and with the major qualitative features of the high energy data, is the subject of this note. Utilizing a rapidity space decomposition of the full $n \to m$ scattering operator and a simple direct channel unitarization program, we shall show that consistent

assumptions about Regge behavior require a relationship between multiperipheral and fragmentation mechanisms. Pomeron couplings to elastic and inelastic channels at finite energies require a cut structure which consistently evades decoupling theorems based on factorization. These issues also have a direct bearing on the sign of the two-pomeron cut discontinuity [7]. The (s-channel) S-matrix calculation of Abarbanel [8], for example, assumes independence of the one- and two- (or more) cluster production mechanisms and obtains a plus sign for the two-pomeron discontinuity. The interdependence of the mechanisms is related to the occurrence of negative cut contributions.

We first set up a notational formalism. Introduce the diagonal projection operator $\mathcal{P}$ which operates on the space of physical particle states, projecting those configurations involving specific numbers of rapidity gaps greater than some value Δy. It may prove useful to take $\Delta y = (1 - \epsilon)Y$, where $Y = \ell ns$ and ϵ is a constant, but the generality of the unitarity argument does not depend on this choice. This procedure separates the full $n \to m$ scattering operator T_{nm} into a sum of terms which will be denoted by superscripts indicating the number of rapidity gaps in initial and final states. For example, the matrix element of T^{11}_{nm} is the physical amplitude in the kinematic region in which n particles with one large gap go to m particles with a similarly large gap. For $n = m = 2$, this is the elastic amplitude and $\Delta y = Y$. We expect the amplitude in this region to be Regge dominated with leading pomeron pole. Similarly T^{10}_{nm} describes the exact amplitude in the kinematic circumstance in which n particles with one gap (where n may be 2) go to a set of particles with no large gaps. Multiperipheralism might be an adequate

description of the amplitude in this region. At high energies, one expects large gaps to predominate in low multiplicity states while large gap fluctuations in high multiplicity states would seem unusual on statistical grounds. At current energies, zero-gap and one-gap states seem to exhaust the phenomenologically distinguishable final states and hence a two component picture, $T_{2n} = T^{10}_{2n} + T^{11}_{2n}$, seems reasonable.

We can apply the same analysis to the many body unitarity relation to establish a nonlinear connection between these suggestive dynamical regions. Thus

$$\mathrm{Im}\, T^{ij}_{nm} = \sum_{k,\ell} T^{*ik}_{n\ell} \rho_\ell^{\,k} T^{kj}_{\ell m} \tag{1}$$

where $\rho_\ell^{\,k}$ is the k-gap projection of ℓ-body phase space, and Σ is a generalized sum and invariant phase space integral. This equation is correct only to the extent that we can neglect disconnected parts and anomalous thresholds. We shall assume, for convenience, that this is possible. The $2 \to 2$ form of this equation (which is always correct) is

$$\mathrm{Im}\, T^{11}_{22} = \sum_n T^{*10}_{2n} \rho_n^{\,0} T^{01}_{n2} + \sum T^{*11}_{2n} \rho_n^{\,1} T^{11}_{n2} + \cdots \quad . \tag{2}$$

If T^{10} were precisely multiperipheral and T^{11} purely pole-behaved, then we would obtain the usual ABFST [9] pole and cut with relative plus sign. However, let us carry through the ABFST program, in a qualitative fashion, but generate the pole and cut contributions through a generalization of the unitarization scheme of Baker and Blankenbecler [10] and Dash, Fulco, and Pignotti [11]. This will allow

us to isolate the pole and cut contributions to one cluster (no gaps), and to two-cluster (one gap) production, and the corresponding contributions to the $2 \to 2$ absorptive part, $A(s,t)$.

We introduce approximate amplitudes B^{10}_{nm}, B^{01}_{nm}, and B^{00}_{nm} appropriate to the kinematic separation above. These "Born" terms will be assumed to have no important s-discontinuities. One may regard B^{10} as a multiperipheral chain, although it is not necessary to do so. It is also not necessary to introduce a bare pole, B^{11}, as the exact T^{11} can be generated from the original terms by the usual ABFST mechanism. The projections of the unitarity equations which must be satisfied are

$$\begin{aligned}
\mathrm{Im}\, T^{11} &= \sum T^{*10}\rho^{0}T^{01} + \sum T^{*11}\rho^{1}T^{11} + \cdots \\
\mathrm{Im}\, T^{10} &= \sum T^{*10}\rho^{0}T^{00} + \sum T^{*11}\rho^{1}T^{10} + \cdots \\
\mathrm{Im}\, T^{00} &= \sum T^{*00}\rho^{0}T^{00} + \sum T^{*01}\rho^{1}T^{10} + \cdots .
\end{aligned} \tag{3}$$

The generalized Lippman-Schwinger constraint equations relating the exact T^{ij} to the approximate input amplitudes B^{ij}, in such a way that the above equations are satisfied, are

$$\begin{aligned}
T^{00} &= (1 + T^{00})B^{00} + T^{01}I^{1}B^{10} \\
&= B^{00}(1 - I^{0}B^{00})^{-1} + T^{01}I^{1}B^{10}(1 - I^{0}B^{00})^{-1} \\
&\equiv \tilde{B}^{00} + T^{01}I^{1}\tilde{B}^{10} \\
T^{01} &= B^{01}(1 + I^{1}T^{11}) + B^{00}I^{0}T^{01} \\
&= \tilde{B}^{01}(1 + I^{1}T^{11}) \equiv \tilde{B}^{01}(1 - I^{1}R^{11})^{-1} \\
T^{10} &= (1 + T^{11}I^{1})\tilde{B}^{10} \equiv (1 - R^{11}I^{1})^{-1}\,\tilde{B}^{10}
\end{aligned}$$

Equation (4) continued next page

Equation (4) continued

$$\begin{aligned}
T^{11} &= T^{10}I^{0}B^{01} \\
&= (1 + T^{11}I^{1})R^{11} = (1 - R^{11}I^{1})^{-1}\,R^{11}
\end{aligned} \tag{4}$$

where $I_n^{\,k}(s)$ is a real analytic function of s which has imaginary part $\rho_n^{\,k}$ on the physical s cut. This representation is possible under rather general assumptions [11] in either impact parameter representation or generalized partial wave projections of the amplitudes.

In eqs. (4) we have identified the exact "pole" R^{11} as $\tilde{B}^{10}I^{0}B^{01}$ where the lowest order term, $B^{10}I^{0}B^{01}$, has the absorptive part associated (in the multiperipheral case) with the ABFST pole. That one must be cautious about the renormalization ("final state interactions" due to B^{00}) effects is evidenced by the model of Auerbach, Aviv, Blankenbecler, and Sugar [12] where the eikonal sum over grid graph poles, implicit in $\tilde{B}^{10}I^{0}B^{01}$, builds a hard "unitarity cut." We will ignore these effects here and assume R^{11} is an ordinary (ABFST) Regge pole. Then the absorptive part of T^{11} is, from eqs. (3) and (4)

$$\begin{aligned}
A(s,t) &= \sum (1 + T^{*11}I^{*1})\, B^{*10}\rho^{0}B^{01}(1 + I^{1}T^{11}) \\
&\quad + \sum (1 + T^{*11}I^{*1})R^{*11}\rho^{1}R^{11}(1 + I^{1}T^{11}) + \cdots \\
&\approx \sum (1 + R^{*11}I^{*1})\,\mathrm{Im}\, R(1 + I^{1}R^{11}) + \cdots \\
&\quad + \sum (1 + R^{*11}I^{*1})R^{*11}\rho^{1}R^{11}(1 + I^{1}R^{11}) + \cdots \\
&\approx [\mathrm{Im}\, R + R^{*11}\rho^{1}R^{11}] \otimes [1 + 2\,\mathrm{Re}(I^{1}R^{11}) + \ldots] \\
&\equiv \mathcal{R}[1 - \lambda\, C_2/\mathcal{R} + \cdots] + C_2[1 - \lambda^{1}C_3/C_2 + \ldots]
\end{aligned} \tag{5}$$

Graphically, this sequence is fig. 1, where the dotted line indicates the factor I^1. It is only the imaginary part of this function which corresponds to real intermediate states. If I^1 is dominated by its absorptive part [11], so that $I^1 \approx i\rho^1$ (where quasi-two-body phase space has the value $\rho^1 \approx 1/2s$ at large s), we find that the cut contribution to $A(s,t)$ from one cluster (no-gap) production may be negative [13] if $\mathrm{Im}\, R > \mathrm{Re}\, R$. For the pomeron, which is assumed purely imaginary at $t = 0$, under these approximate circumstances, we have the familiar statement that unitarity "reverses the sign" of the P-P cut [14,11]. This optimal circumstance requires $\lambda = \lambda^1 = 2$.

Let us now consider the general consequence of this picture. The result of the presence of a lower multiplicity fragmentation channel is to shadow the multiperipheral mechanism. This is the familiar quantum mechanical statement of absorption into the competing two-cluster, pole-dominated, production channel and is reflected in the negative cut contribution (C_2) to the one-cluster amplitude. The two-cluster production mechanism also has a negative cut shadow (C_3) which one may think of as due to the high multiplicity multiperipheral contribution to production. The latter, by sharpening the forward diffractive peak, reduces the two-cluster amplitude in the high missing mass, or high multiplicity, region. For further consistency we note that the negative cut in T^{11} [which contributes to the three-reggeon cut in $A(s,t)$] reproduces itself in the negative output two-reggeon discontinuity in $A(s,t)$. As we shall see below, this is qualitatively sufficient to cure both the Finkelstein-Kajantie [1] disease and that associated with nonvanishing triple-pomeron coupling [4]. This should not be surprising since we have forced unitarity. The net negative

cut contribution, if it ultimately falls with energy, serves to delay the onset of multiperipheral production asymptotics. This is a direct consequence of the assumption of a pomeron contribution to elastic and production processes at finite energies. The evolution of this picture will be a function of the pomeron slope.

If the low-multiplicity mechanism is to prevent the multiperipheral mechanism from violating unitarity in the manner of Finkelstein and Kajantie then one has an apparent paradox since the violation there may seem to come from the high multiplicity $(N \approx \ell n s)$ region and it is hard to see how a shadow in the low multiplicity channel can affect this region. The resolution is that the proof in that paper is incorrect for $\ell n(s)$ multiplicities [15]. A lower power bound can be obtained only from much smaller multiplicities, of order $\epsilon\, \ell n(s)$ in the most extreme case [16], where ϵ is a small number and the lower power bound depends on this parameter and the pomeron-particle-pomeron coupling. This motivated our choice of the minimum Δy. If such multiplicities go through a fragmentation mechanism, where there is only one very large rapidity pomeron link, instead of through a multi-pomeron chain with all relative rapidities large, then the multiperipheral mechanism is shadowed by the former mechanism in precisely the manner necessary to prevent a unitarity violation. The dynamical reason why low multiplicities condense in low-subenergy fashion at the ends of the Feynman cylinder is not furnished by our arguments which only show that if this is true, then consistency with this aspect of unitarity may be obtained by the above cut relationships. We will have a more general suggestion at the end.

The suppression of high mass (and multiplicity) diffractive states by absorption into the multiperipheral channel and the consequent negative cut in T^{11}, which sharpens the forward quasielastic peak, indicates that these effects provide a shielding mechanism for the triple-pomeron coupling. An example of this has been given by Caneschi and Schwimmer [17] in the Finkelstein-Zachariasen [18] absorptive model but the effect is considerably more general. The low missing mass region is not as strongly affected by the sharpening of the diffractive peak since it involves smaller t-values. Duality arguments about (nonscaling) PPR contributions still obtain. The PPP contribution must become integrable for models satisfying our unitarity constraints. These effects will sharpen the forward peak in the leading proton x-distribution in pp inclusive reactions and affect the dip at $x = 0.9$ there.

There are additional features of this picture which are somewhat more model dependent. If the full sign reversal $(\lambda = 2)$ occurs, then we can establish a connection between the amount of diffractive production [the positive cut contribution from the two-cluster contribution to $A(s,0) \approx \sigma_{tot}$] and the pole-cut interference minimum in $d\sigma_{e\ell}/dt$ at $-t = 1.2$ GeV/c. In this case the two-cluster production has the same ratio to multiperipheral production as the strength of the net negative cut in $A(s,t)$ relative to the pole. With the simple (and probably inadequate) Regge parametrization

$$A(s,t) \approx \beta_P(t)\, s^{\alpha_P(t)} \left[1 - \frac{(\lambda - 1)\, \beta_c\, e^{-(a+\alpha' \ell ns)t/2}}{\beta_P(a + \alpha' \ell ns)} \right] \tag{6}$$

[with $\lambda = 2$, $a = 3$, $\alpha' = 0.5$, $\ell ns = 8$, $\beta_P(t) = \exp(at)$], we find that the dip appears in the proper place with a relative cut to pole strength of 10-20%. This is in good agreement with the estimated amount of diffractive production at ISR energies. If the cut discontinuity does not vanish at $t = 0$ then σ_{tot} will rise logarithmically (if $\alpha'_P \neq 0$) at ISR energies. An additional effect of the net negative cut is to counter the strong shrinkage due to the pomeron slope. The point t_0 in $d\sigma_{e\ell}/dt$ at which the cut begins to compete with the pole moves in toward $t = 0$ as s increases since the cut has a smaller but energy dependent slope. The cut dominates beyond the interference minimum, which moves slowly in toward $t = 0$.

The energy dependence due to the pomeron slope is interesting. If the slope is nonvanishing, then elastic and diffractive cross sections, and hence the shadow of this mechanism on the multiperipheral mechanism, must die away asymptotically. This would leave the multiperipheral mechanism to asymptotically generate only a pomeron pole contribution to $A(s,t)$, and hence a constant total cross section. Thus a moving pole contribution to inelastic reactions at finite energies requires an accompanying cut structure which prevents factorization at finite energies but which disappears asymptotically. This requires that the elastic cross section vanish at infinity, but will be masked even at ISR energies by the disappearing negative cut. If $\alpha'_P \equiv 0$, then nonfactorization will be asymptotically sustained. We should then keep the entire hierarchy of cuts and the resulting picture is essentially geometrical. The dip in $d\sigma^{PP}_{e\ell}/dt$ will remain fixed and the percentage of diffraction dissociation will stay constant. In either case, there will be long range correlations, probably of the

10-20% order of the relative cut strength. Since the nonfactorization of the pomeron is due (through unitarity) to its couplings at finite energies to elastic and inelastic channels, the usual theorems about decoupling would seem irrelevant to this situation.

The cut structure described above was made necessary by the lack of any dynamical mechanism which would result in condensation of low multiplicites near the ends of the rapidity axis. The multiperipheral mechanism spreads even small multiplicities relatively uniformly over the rapidity axis with exponentially damped fluctuations. This leads to a gas analogy in which a multiplicity $\epsilon\, \ell n(s)$ corresponds to a gas pressure ϵ. As we have seen, if the pomeron has intercept one, then the unitarity violation arises from these smaller multiplicities or pressures. The unitarity constraint provides a long-chain correlation which appears explicitly in the cut structure above and which becomes important at lower multiplicities.

The appearance of a correlation length with the dimensions of the entire system is just the circumstance describing a phase transition. In the approach to a phase transition, groups of particle begin to act collectively, with the interaction between groups the <u>same</u> as that originally acting between individual particles. In our case the force is pomeron exchange and the collective entities are those associated with diffractive fragmentation. Thus when the gas pressure (multiplicity) drops to the point at which iterated pomerons in the multiperipheral chain saturate unitarity, a phase transition occurs and single pomeron exchange between clusters dominates. The pressure in the center of the rapidity axis is then zero. The energy dependence of this link is $s^{(1-\epsilon)\alpha(t)}$ and the largest missing mass is s^{ϵ}. The

integrated diffractive contribution, from these masses is $(g\beta_P{}^2\epsilon)/(32\pi\alpha')$. This is very similar to the result when the pomeron intercept is below one and the usual triple-Regge assumptions are made [4]. The pomeron intercept thus seems to play the role of a critical exponent. If the intercept is below one, the critical pressure is presumably zero and an ideal gas of a few particles is allowed.

If the critical point is between zero and $\ell n(s)$ multiplicities, then both diffractive and multiperipheral mechanisms operate at finite energies. It is possible that this critical point behavior is reflected in the singularity structure since the analyticity properties of such a situation are not well defined. One possibility is the collision of hard cuts with the leading j-plane pole at $j = 1$. This is the natural occurrence in eikonal models, which satisfy our unitarity equations. If the pomeron intercept is below one, pole and branch points are separated and the anlyticity properties are well defined. This is consistent with our conjecture that this situation corresponds to no phase transition or a critical pressure of zero. A more detailed exploration of these issues will appear elsewhere.

ACKNOWLEDGMENTS

Much of this work follows from discussions with R. Blankenbecler and G. F. Chew. The critical influence of H. Stapp is much appreciated, as are conversations with M. R. Pennington, S. Auerbach, C. Rosenzweig, and M. Bishari. I thank J. D. Jackson for reading the manuscript and M. Kugler for his comments on an earlier version.

REFERENCES

1. J. Finkelstein and K. Kajantie, Nuovo Cimento 56A, 659 (1968) and Phys. Letters 26B, 305 (1968).

2. R. Rajaraman, Phys. Letters 42B, 271 (1972) and references therein.

3. R. C. Brower and J. H. Weis, Phys. Letters 41B, 631 (1972).

4. H. D. I. Abarbanel, G. F. Chew, M. L. Goldberger, and L. M. Saunders, Phys. Rev. Letters 26, 937 (1971).

5. K. G. Wilson, Cornell Preprint CLNS-131 (November, 1971, unpublished).

6. G. Goldhaber, CERN Preprint D.Ph II/PHYS 72-46; P. Pirilä and P. V. Ruuskanen, CERN-TH.1551 (1972); K. Fiałkowski, Rutherford Preprint RPP/T/28 (1972); W. R. Frazer, R. D. Peccei, S. S. Pinsky, and C.-I. Tan, UCSD-10P10-113 (October, 1972); H. Harari and V. Ravinovici, Weizmann Preprint (November, 1972); C. Quigg and J. D. Jackson, NAL-THY-93 (October, 1972, not for publication).

7. F. E. Low, Rapporteur's talk at 16th International Conference on High Energy Physics at Batavia, Illinois (October, 1972). G. F. Chew, Arguments Supporting a Positive 2-Pomeron Discontinuity, Batavia Conference and Lawrence Berkeley Laboratory Report LBL-1338.

8. H. D. I. Abarbanel, Phys. Rev. D6, 2788 (1972); A. R. White, Cambridge Univ. Report, DAMTP 72/18. This is really an S-matrix calculation in t-channel formulation. If the difficult continuations are correct, and hence the negative cut sign, this treatment should reveal some of the features suggested here and hence the source of disagreement with Abarbanel's calculation. The basic difference between reggeon calculus and field theory computations and the simple unitarity construction through pole contributions

is that the former allow consideration of two-reggeon contributions to the full elastic amplitude. The total discontinuity of these amplitudes includes terms which do not arise in the unitarity construction. This has been concisely demonstrated by R. Blankenbecler, SLAC-TN-72-13 (September, 1972, unpublished). Many of the basic elements of our work result from a formalization of and extrapolation from the ideas presented here.

9. L. Bertocchi, S. Fubini, and M. Tonin, Nuovo Cimento 25, 626 (1962); D. Amati, A. Stanghellini, and S. Fubini, Nuovo Cimento 26, 6 (1962).

10. M. Baker and R. Blankenbecler, Phys. Rev. 128, 415 (1962).

11. J. W. Dash, J. R. Fulco, and A. Pignotti, Phys. Rev. D1, 3164 (1970). The real part of I^1 is constrained, by requirement of definite signature of the cut, to be small at high energies. See also Luca Caneschi, Phys. Rev. Letters 23, 254 (1969). Our work is much in the spirit of this paper.

12. S. Auerbach, R. Aviv, R. Blankenbecler, and R. Sugar, Phys. Rev. D6, 2216 (1972).

13. Note that the negative terms are generated from the dispersive part of T_{2n}^{10} and will not appear in the absorptive part of this amplitude. The dispersive part is included to insure satisfaction of the full set of unitarity equations for T^{ij}. This might be described as a protocut contribution--only when inserted in the sum on the right-hand side of a unitarity sum does it generate a cut contribution.

14. J. Finkelstein and M. Jacob, Nuovo Cimento 56A, 681 (1968).

15. Private communication from R. Sugar and J. Botke and to be published. For $\ell n(s)$ multiplicities the t_{min} associated with each multiperipheral link does not go to zero as s increases. Instead, $t_{min} \approx -(m^4)/(s_i)$ where $\ell n(s_i) \approx \ell n(s)/\langle n \rangle \approx$ constant. The truly (in the ABFST sense) multiperipheral region adds another random walk step instead of letting subenergies increase.

16. For these smaller multiplicites, at fixed s, the enlarged phase space compensates and one can obtain a lower power bound by the method of Finkelstein and Kajantie. This has been shown by G. F. Chew and J. Koplik. It was independently demonstrated to me by S. Auerbach. Note that if one restricts phase space by forcing clustering at the ends of the rapidity axis then the problem is avoided.

17. L. Caneschi and A. Schwimmer, Nucl. Phys. B48, 519 (1972).

18. J. Finkelstein and F. Zachariasen, Phys. Letters 34B, 631 (1971).

FIGURE CAPTION

Fig. 1. (a) The cut structure associated with production into states with no large rapidity gaps. The solid line represents the absorptive part being considered; the dotted, the factor I^1 described in the text.

(b) Cut structure associated with two-cluster production.

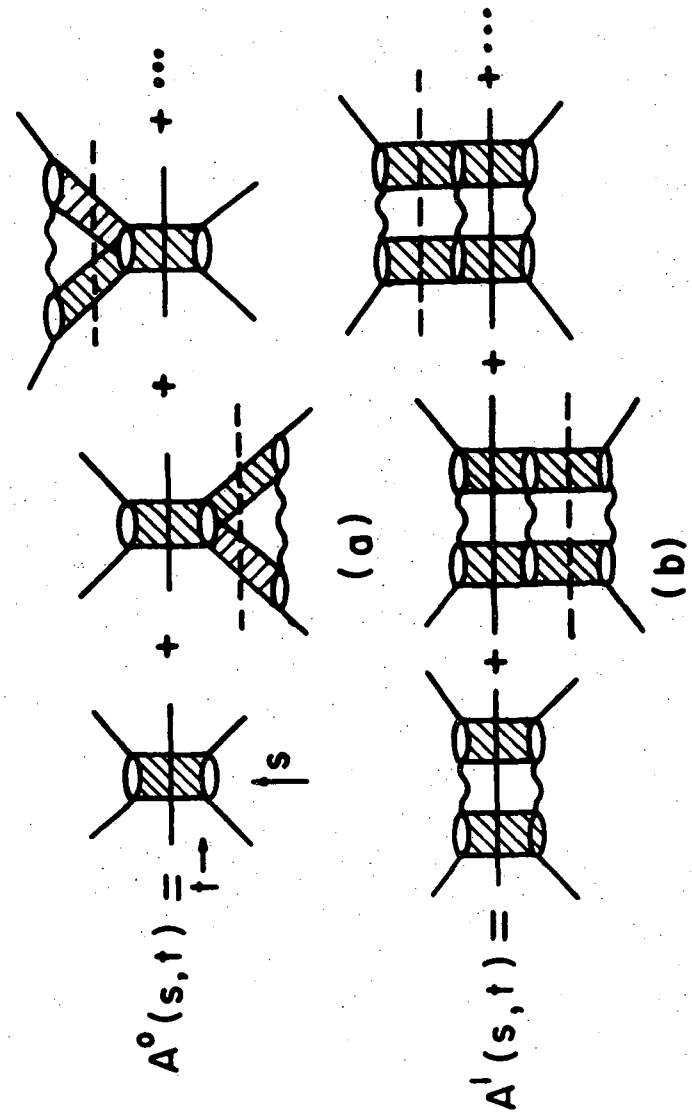

Fig. 1

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