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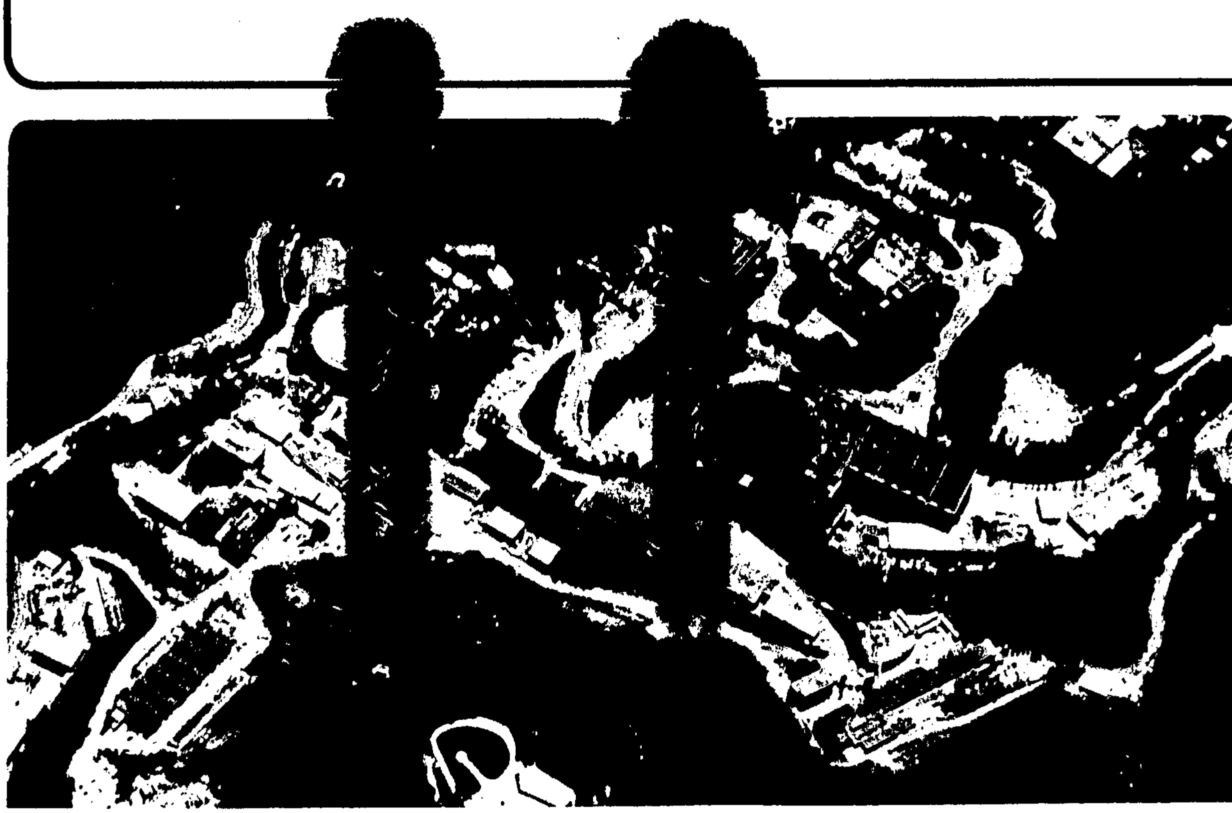

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A SINGLE-SHEET CLASSICAL SURFACE FOR ELECTROWEAK HADRONIC CURRENTS*

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Abstract

Recent modifications in the topology of chirality and "color" are incorporated into a representation of electroweak hadron interactions. It is shown that a connected oriented thickened momentum graph, housed in a single sheet of the classical surface, can represent a minimal electroweak hadronic vertex.

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I. INTRODUCTION

A topological theory of electromagnetism has been put forward in Ref. 1 based on the quantum-classical surface pairs introduced in Ref. 2 for strong interactions. Recently, modifications in the representation of "color" and of chirality in the theory of Ref. 2 have been suggested,[3,4] and we here investigate changes required in electroweak topology by these color-chirality innovations.

We focus on the classical surface together with its charge and momentum graphs. Our lowest-level hadronic electroweak currents are now devoid of "momentum structure"--the associated amplitudes having no singularities in any momentum variables. The classical surface houses a thickened oriented momentum (Feynman-Landau) graph with charge arcs located along its boundary; electric charge correlates with agreement or disagreement between charge-arc direction and orientation of the thickened Landau graph.

Recently-published estimates of baryon magnetic moments[5] are undisturbed by the modifications of Ref. 1 proposed here; also, companion alterations of lepton-current topology--described in Ref. 6--preserve the conclusion of Ref. 1 that topological lepton-photon interactions accord with perturbative Q.E.D. The principal physical impact of the innovations in this paper will be for weak interactions.

II. MINIMAL HADRONIC VERTEX: GENERAL SURFACE-PAIR CONSIDERATIONS

The Ref. 1 notion of minimal electromagnetic components of the topological expansion, extended by Ref. 7 to minimal electroweak components, is to be replaced here by a set of similar but more restrictive topologies that we call "minimal electroweak vertices." The most general electroweak topology is to be built by connected sum starting from minimal vertices, which admit an immediate "off-mass-shell" significance. Each topology within the topological expansion is associated with an amplitude, and minimal vertices are amplitudes for the interaction of an electroweak vector or scalar boson with a pair of elementary particles, the momentum (Feynman-Landau) graph being a single-vertex cubic tree. By contrast the minimal electromagnetic component of Ref. 1 allowed more than 2 hadrons. A minimal vertex cannot itself be built by connected sum from any other components of the topological expansion, so the associated amplitude has no discontinuities in momentum variables. There is correspondingly no ambiguity in defining the minimal-vertex amplitude for arbitrary values of momentum variables through a single real coupling constant which we expect to identify with e--the elementary electric charge. By contrast the fact that the minimal electromagnetic component of Ref. 1 included a trivial hadron vertex as well as a cubic electromagnetic vertex meant that the associated amplitude had structure (i.e. singularities) in hadron momentum. The value of the amplitude for arbitrary values of hadron momentum was not immediately prescribable.

Minimal hadron vertices maintain the Ref. 1 feature that the classical surface Σ_C has two boundary (belt) components--one belonging entirely to the electroweak boson while the second belongs to the hadron pair. Intersecting (thickening) each belt component is a closed quantum-

surface (Σ_Q) component divided into triangles. Although this paper focusses on Σ_C, some general remarks at this point about Σ_Q are needed.

Each quantum triangle meets the belt and carves out one I-shaped or Y-shaped subpiece thereof[8] as shown in Fig. 19 of Ref. 2. Quantum triangles may correspondingly be designated as either I or Y triangles, a terminology that we here prefer to "peripheral-triangle" and "core-triangle"--the language used in Ref. 2. For hadrons, I triangles usually lie along the perimeter of a bounded hadron area, but in electroweak bosons I-triangles are never peripheral; the quantum area belonging to an electroweak boson is always a closed surface covered by two triangles. The Σ_Q topology of a minimal hadron vertex includes a second closed surface covered by the hadron pair; a meson-pair surface has 4 triangles, a baryon-pair surface has 8 and a baryonium-pair surface has 12.[2]

Every quantum triangle is mated in a topologically-precise sense[2] to exactly one other quantum triangle on the same component of Σ_Q. Each triangle contains the end of exactly one charge arc lying in Σ_C, and a hadronic minimal vertex couples a mated pair of hadron triangles via charge arcs to the mated triangle pair building an electroweak boson. Charge arcs connecting nonmated triangles, typically on different components of Σ_Q, are designated as "active" and those connecting mated triangles as "passive". In a minimal hadron vertex there are exactly two active charge arcs--connecting the two separate components of Σ_Q. On each component the ends of the two active charge arcs lie inside a mated pair of triangles. All the ideas of this paragraph have been introduced in Ref. 1 and are maintained unchanged here.

III. SINGLE-SHEET Σ_C FOR "WEAK HADRON PROPAGATORS"

At zero entropy Σ_C is multisheeted, the sheets joining in threes at junction lines whose ends lie in Y triangles--each end at a Y vertex of the belt.[2] Charge arcs attached to Y triangles also have each end at a Y vertex and lie "close" to associated junction lines, while charge arcs attached to I triangles are "close" to the belt.[2] (Charge arcs never cross momentum arcs or each other.) Each sheet carries at least one I-charge arc although only one sheet carries the momentum graph together with all Y-charge arcs. One of the recent modifications of the Ref. 2 theory was a prescription for hadron plugs ensuring that, even for nonzero entropy, any strong-interaction momentum graph lies on a single oriented sheet--never crossing a junction line. Σ_C then houses an oriented thickened momentum graph. We assume that such smoothness of momentum flow should be maintained by electroweak topologies. Because the electroweak boson boundary connects with the momentum graph and must also be connectable to every charge arc, it follows that Σ_C for a minimal electroweak vertex is single sheeted.

Ref. 3 speaks of distinct momentum graphs colored #1, 2 or 3. The (connected) momentum graph referred to above corresponds to that colored #1 and is the familiar Feynman-Landau graph. The graphs #2 and #3 are trivial and at zero entropy are disconnected; they are needed for the representation of chirality and should not be regarded as carriers of momentum. Although called "momentum-copy" arcs in Refs. 3 and 4, they might also be described as "diquark color arcs", as will be evident from what follows.

A convenient approach to hadron minimal currents is to start with a surface pair (Σ_Q, Σ_C) that corresponds to a hadron "weak propagator"

and then to insert an electroweak boson. Physical motivation for such an approach comes from the familiar idea (crucial to the measurement process) of soft photon emission and absorption by a particle propagating almost freely. (The classical significance of electric charge depends on this idea.) So we now seek single-sheet "weak propagators" for elementary mesons, baryons and baryoniums, recognizing that these topologies do not appear within the topological expansion until augmented by electroweak-boson insertion. (As discussed in Ref. 2 hadron propagators do appear in the topological expansion and should not be confused with weak propagators.)

For a baryonium weak propagator the unique single sheet of zero genus is shown in Fig. 1. There are two junction lines, one with ends labeled (a, b) and the other with ends labeled (c, d). The three heavy (a, b) line segments in the figure are to be identified as a single junction line, as are the three heavy (c, d) line segments. The belt consists of the light line segments, while the dashed line is the baryonium momentum arc. Momentum-copy arcs not shown in Fig. 1 will make the central vertex nontrivial. Eventually the electroweak-boson momentum arc also will attach to this vertex. The wiggly lines are charge arcs connecting triangle mates of opposite orientation. Each Y-charge arc (attached to a junction line) has 3 potential locations and a unique choice is required. The location shown in Fig. 1 has been selected because there is no way of choosing between the other two possibilities. It is seen that the Σ_Q triangle orientations collectively impart a coherent global (HR) orientation to Σ_C. Note also how the momentum arc divides Σ_C into two "halves," corresponding to a diquark-antiquark structure for baryonium.

The "passive" charge arcs in Fig. 1 might as well lie along the hadron belt or along junction lines, but if one of these becomes "active" through coupling to an electroweak boson, this charge arc leaves the neighborhood of the hadron belt or junction line and forges a link between the electroweak-boson belt and the hadron belt (Fig. 6 below). Section V will discuss the location of active charge arcs.

The single-sheet baryon propagator is shown in Fig. 2. Note that the top half of this figure is identical to the top half of Fig. 1; we may think of this half as a "diquark region" of Σ_C and the bottom half of Fig. 2 as the "quark region".

In Fig. 3(a) we show the baryon propagator again, this time displaying the momentum-copy arcs (or diquark color arcs). The numbers at the ends of the (copy) arcs represent the "colors" of the portions of Σ_Q where the arc ends lie;[2,3] color #1 denotes the actual momentum arc. We are assuming Σ_Q to be a sphere, an assumption that dictates the numbering pattern in Fig. 3(a). In Fig. 3(b) we display the baryonium propagator including the momentum-copy arcs.

To complete the set of hadron propagators we give in Fig. 4 the meson propagator Σ_C, which corresponds to a quark-antiquark structure. There are here no diquarks or copy arcs.

In Ref. 4 any zero-entropy Σ_C is divided into local areas by the momentum graph together with momentum-copy arcs. A local Σ_C area carries an orientation if and only if adjacent to an I-triangle on Σ_Q that shares with a different I triangle its two (generation-carrying) edges uncut by the belt. Such an I triangle we characterize as "peripheral"--following the terminology of Ref. 2. For hadrons, peripheral I-triangles have also been called "topological quarks". Peripheral I triangles carry a chirality controlled by the local

orientation of the adjacent Σ_C area. Each mated pair of peripheral I triangles carries an independent chirality at zero entropy--i.e., is adjacent to an independently-oriented area. We assume all of the foregoing features to be maintained by electroweak interactions. The areas in Figs. 3 and 4 which contain charge arcs and do not touch junction lines are locally-oriented chiral areas, each adjacent to exactly one mated (in-out) pair of topological quarks. The remaining areas are not adjacent to peripheral I-triangles and, correspondingly, are not locally oriented. Note that each of the nonoriented areas in Fig. 3 is adjacent to a junction line and that oriented areas do not touch junction lines--maintaining this feature of strong-interaction topology.[4]

IV. INSERTION OF ELECTROWEAK BOSONS INTO Σ_C

Our approach to minimal electroweak hadronic vertices adds an electroweak-boson boundary to the single-sheet hadron "weak propagator" Σ_C and joins the hadron boundary to the boson boundary with a pair of active charge arcs as well as with the momentum graph. The detailed structure of the electroweak boson boundary remains to be developed. Suffice it for the moment to say that, because the boson Σ_Q is built from two triangles, these are two pieces of boson belt each of which receives the end of one active charge arc. The boson momentum arc ends at a point where the two belt pieces meet. For the purposes of the present section the electroweak-boson component of the Σ_C boundary can be thought of as given by Fig. 5, possible modifications of which will be explained in a separate paper. The possible modifications involve a crosscap on Σ_C and will depend on whether the boson is vector or scalar.

Any hadron vertex couples an electroweak boson to one mated pair of triangles in the hadron area. Thus a baryonium vertex can be formed in six possible ways, two of which couple the boson to Y-triangles and four to I-triangles ("quarks"). Because each passive charge arc lies in a distinct local area of Σ_C, delineated by momentum arcs and momentum-copy arcs, it is natural in constructing each vertex to insert the electroweak boson into the corresponding area--so that charge arcs touch no other arcs and momentum arcs touch each other only at the single central vertex. Fig. 6 gives the example of electroweak coupling to a baryonium Y triangle. The form of the other five baryonium couplings is evident, as is the form of baryon and meson electroweak couplings.

V. DISCUSSION

The approach of this paper has not stemmed from any recognized "raison d'être" for electroweak interactions, although a candidate electroweak bootstrap mechanism has recently been uncovered in the cylindrical topology generated from zero entropy.[9] Rather we have allowed ourselves here to be guided by general features of the phenomenologically-successful "standard" Weinberg-Salam electroweak Lagrangian model, which is in turn an extension of quantum electrodynamics. Nevertheless, even if it turns out that electroweak interactions can be "bootstrapped" together with strong interactions--that is, shown to be unavoidable aspects of a consistent S matrix--the proposals of this paper may prove relevant and useful. Many aspects of zero-entropy topology were guessed before being bootstrapped.

We are guessing that an oriented thickened momentum (Feynman-Landau) graph with charge arcs along the boundary is essential to consistency of a topological S-matrix expansion. This paper has shown such a requirement to be compatible with the general topological structure suggested by experimentally-observed electroweak facts. Our proposals here easily extend to lepton currents.[6]

ACKNOWLEDGMENT

Discussions with M. Levinson and H.P. Stapp have contributed to the proposals of this paper. This work was supported in part by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098.

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FIGURE CAPTIONS

FIG. 1: Weak baryonium propagator.

FIG. 2: Weak baryon propagator.

FIG. 3: (a) Weak baryon propagator including momentum-copy (diquark color) arcs.

(b) Weak baryonium propagator with momentum-copy arcs.

FIG. 4: Weak meson propagator.

FIG. 5: Neighborhood of electroweak-boson boundary.

FIG. 6: Electroweak boson coupled to baryonium Y triangle.

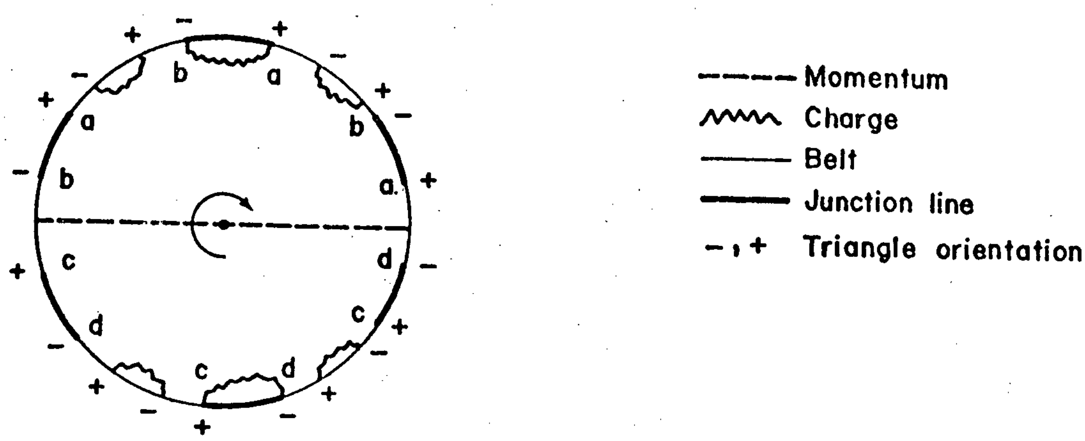

FIG. 1

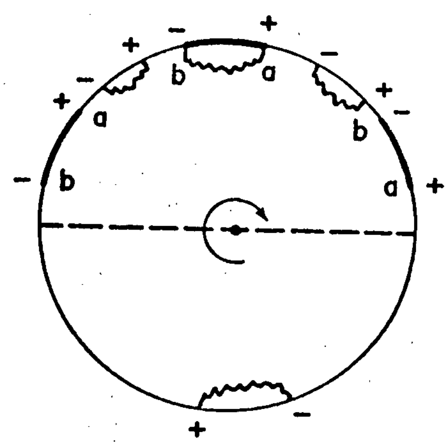

FIG. 2

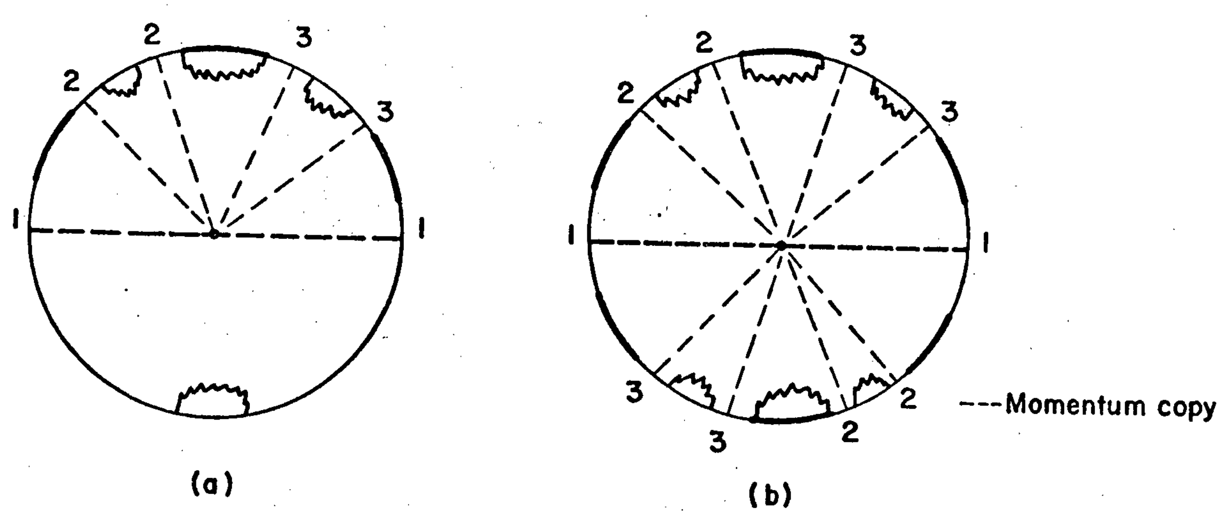

FIG. 3

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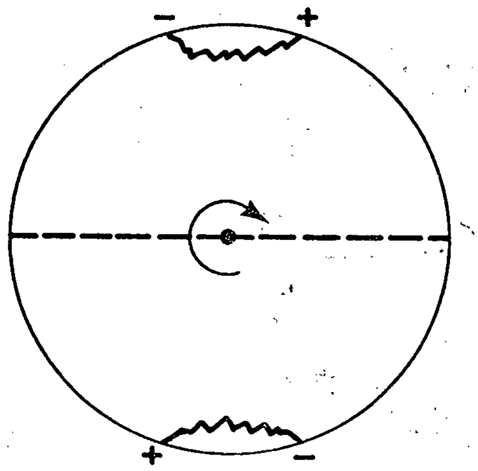

FIG. 4

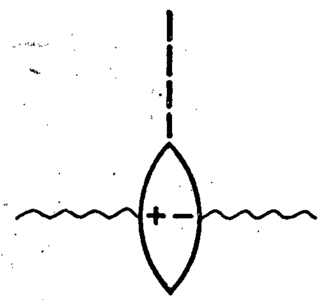

FIG. 5

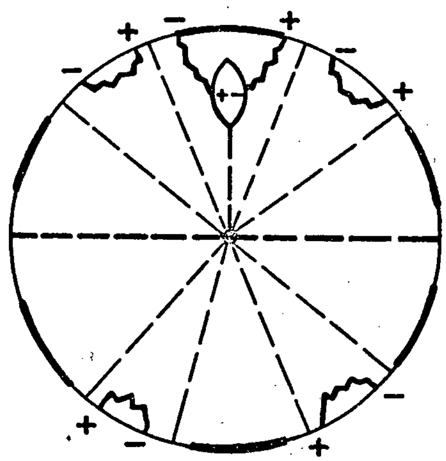

FIG. 6

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