Title

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Publication Date

1983-12-01

LBL-17189
Preprint

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Physics Division

Submitted for publication

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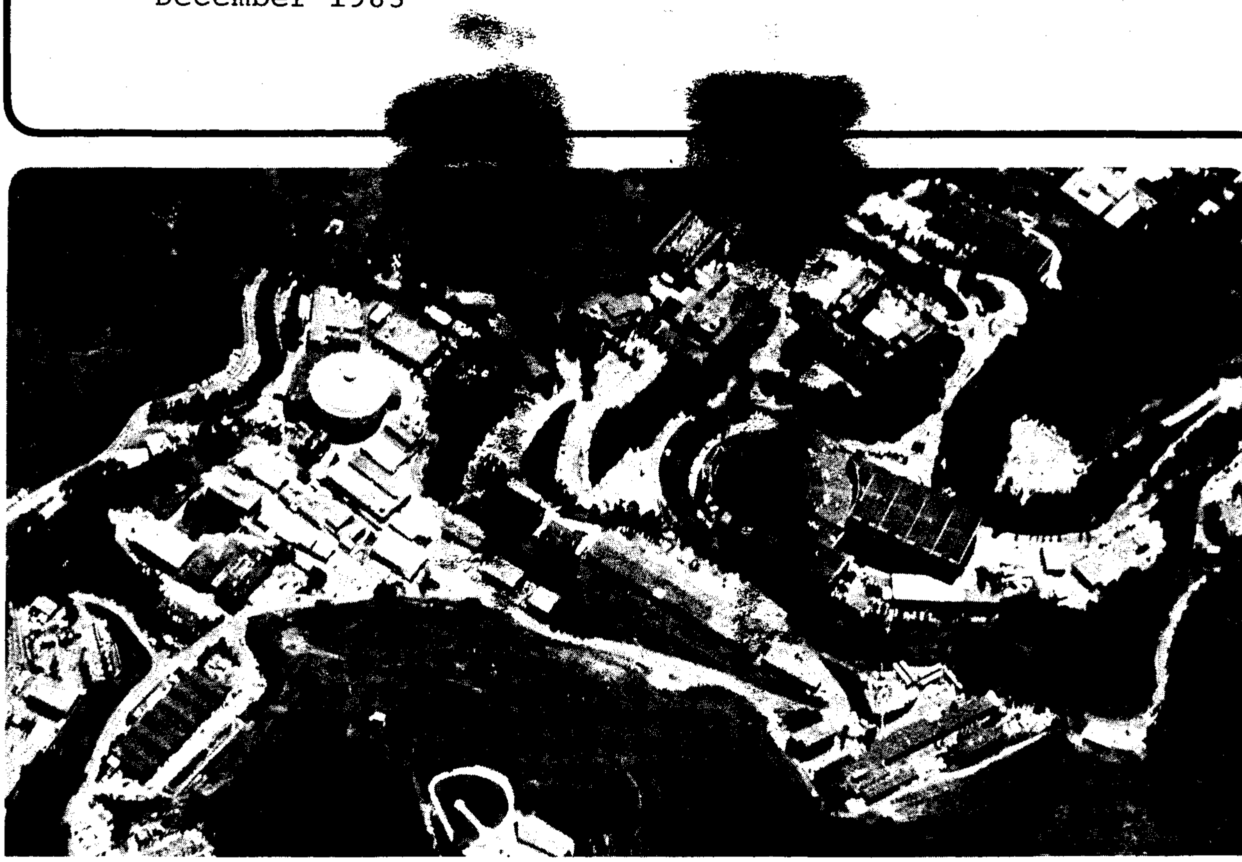
December 1983



Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

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PROTON STABILITY AND 4 LEPTON GENERATIONS FROM UNIFIED TOPOLOGICAL PARTICLE THEORY[1]

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Abstract

With the goal of finiteness for each level of the topological expansion, we propose an electroweak topology where 4 generations of elementary leptons, instead of paralleling quarks, join vector and scalar elementary electroweak bosons in a massless multiplet. Physical lepton and boson masses arise from hadron interactions. The previously-established connection with the standard electroweak model is maintained. Baryon number and lepton number are separately conserved.

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[1] 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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Grand unified field theories treat quarks and leptons in parallel and usually predict instability for protons; it has been conjectured that a unified topological theory would follow suit. The first attempts to topologize leptons provided for one-to-one "quark"-lepton matching, and the heretofore-most-satisfactory proposal tolerated a baryon-lepton transition.(1) The latter, however, required abandoning global orientation of the topology, and field-theoretic quark-lepton parallelism is in any event unachievable in topological theory -- where "quarks" do not carry momentum although leptons do. Later the relevance to lepton topology of a further consideration became appreciated: each level of the topological expansion must be finite. The Feynman rules for purely-hadronic topologies (2) are divergence-free because the contractibility of hadron vertices renders them "soft". Electroweak vertices in contrast, not being contractible, are "hard" in the sense of local field theory. Closed-loop electroweak topologies possess the same potential for divergences as a standard Lagrangian field theory. The idea then arose of pairing electroweak boson and fermion closed loops so as to achieve the divergence cancellation characteristic of supersymmetric field theory. Such pairing requires that lepton topologies be matched with corresponding electroweak-boson topologies, giving up the matching of leptons against quarks.

Unification has not been abandoned as a guiding principle; the Harari-Rosner global orientation governing hadron topologies(3) is extended to the electroweak sector by our proposal. All physical mass scales and all coupling constants have as origin the lowest level of the topological expansion.(4) Baryon number and lepton number, however, are separately conserved; the proton is predicted to be stable.

Our proposal is describable in "topological shorthand" through diagrams of the type invented for mesons by Harari and Rosner(3) and extended later to baryons.(5,6) These diagrams embellish Feynman graphs with globally-oriented <u>fermion</u> and <u>boson</u> lines, as in the examples of Fig. 1(a-c) where fermion lines may be seen as a generalization of Harari-Rosner quark lines.

A generalized fermion-line end may or may not carry a "generation" index q, but fermion lines always carry spin 1/2 and one unit of a fermion number f; each end also always inherits from the complete topology a 2-valued chiral index (making it a Dirac 4-spinor) as well as a two-valued electrospin index[7] (similar to the weak isospin of standard theory[8]) which distinguishes charged and neutral fermion lines. Fermion lines do not carry momentum; momentum is carried by a single Feynman line for each elementary particle.

The name junction line has previously been applied to what we here call a "boson" line. The former term is topologically descriptive of this line's role in the full topology,[5] but, in striving here to connect with widely-understood nontopological concepts such as supersymmetry, we find the latter term more suitable. Boson lines carry no spin but one unit of a boson number b. Figure 2 provides examples of embellished Feynman graphs that contain boson as well as fermion lines. The end of a boson line may or may not carry a 4-valued index ℓ, as we explain below. Boson lines, like fermion lines, do not carry momentum.

The familiar quantities B = baryon number and L = lepton number are related to fermion number and boson number,[F1] which through line continuity are separately conserved, by

$$B = \frac{1}{2}f + \frac{1}{2}b \tag{1}$$

$$L = \frac{1}{2}f + \frac{3}{2}b \tag{2}$$

B and L being separately conserved, line continuity precludes proton decay. As true since early stages of topological theory,[5] the baryon is seen in Fig. 2 to have f = 3 and b = −1, whereas the lepton there has f = −1 and b = +1, reversing the sign of b with respect to Refs. (1) and (7). More significantly, Ref. (1) did not insist on continuity of line orientation. Subsequent investigation has revealed the desirability (with respect to overall

consistency) of a global orientation for any topology--which implies not only continuity of individual line orientations but uniquely the relative orientations shown in Figs. 1 and 2. Complete definition of the global orientation will be given elsewhere, but Fig. 1 suggests the meaning. (Although our shorthand makes the baryon orientations in Figs. 2(a,b) look arbitrary, in the full topology they are unique.[5])

Why do fermion-line ends sometimes but not always carry the index q? The full topology associates a hadronic Feynman-line end with a triangulated hadron disk on a transverse "quantum" surface, each triangular patch containing the end of exactly one boson or fermion line.[5] A 4-valued generation index is thereby bequeathed to any hadronic fermion-line end; this index describes orientations along the hadron-disk perimeter.[5] (Hadronic fermion-line ends have been called "quarks"; the index q correspondingly may be read as "quark" generation.) Previous work has established that a fermion-line end belonging to an electroweak boson carries no generation index--there being no quantum-surface perimeter to orient. We here propose the same to be true for all nonhadronic fermion-line ends.

The leptonic end of a fermion line then carries no generation index. Lepton generation we propose to be unrelated to the perimeter concept and to reside on the end of a boson line. The perimeter concept we now see as associated with contractions; neither leptons nor electroweak bosons being contractible, neither requires a perimeter.

From the beginning of topological particle theory, it has been recognized that hadronic ends of boson lines make no contact with the hadron-disk perimeter and carry no degrees of freedom--all inherited boson orientations within hadrons being "frozen" so that "quark" content along the hadron perimeter completely controls hadron quantum numbers.[5] This boson-line freezing relates to hadronic contraction rules and the principle that contraction is perimeter-controlled. Because no perimeter is now associated with leptons, there is no reason to treat differently the orientations inherited by lepton boson and fermion-line ends; it is natural to suppose that a lepton boson-line end inherits that same pair of 2-valued orientations which, when inherited by a fermion-line end, physically correspond to chirality and electrospin. The index ℓ in Fig. 2 corresponds to this 4-valued bosonic degree of freedom, absent from hadrons.

The significance of ℓ should not be described as "chirality" plus "electrospin" because any boson line is spinless, and a lepton boson line cannot interact with electroweak bosons. The lepton interaction with an electroweak boson, shown in Fig. 2(c), involves only fermion lines, where there resides the entire lepton content of chirality and electrospin. The lepton boson line being untouched in Fig. 2(c), its pair of 2-valued inherited orientations act like a 4-valued conserved lepton generation index ℓ.

In the lepton topology of Ref. (1), leptons had perimeters and the topological meaning of lepton generation was the same as that of "quark" generation. In the newly proposed topology where leptons have no perimeters, the meanings of "quark" and lepton generation are different (equality in the number (4) of values assumed by q and ℓ appears accidental).

Purely electroweak topologies in our proposal are suggestive of a supersymmetric electrospin and parity symmetric $[SU(2)_L \times SU(2)_R \times U(1)_L \times U(1)_R)]$ gauge-invariant Lagrangian for massless scalar, vector and spinor fields, even though the local-field concept, as explained below, is inapplicable to elementary hadrons. Figure 1(c) represents either Yang-Mills (3 vectors) or vector-scalar coupling, Ref. (9) explaining how chiral labels [not shown in Fig. 1(c)] on the fermion lines distinguish scalars from vectors. Figure 2(c) similarly describes lepton coupling either to scalars or to vectors. The action of a supersymmetry generator plausibly corresponds to interchange of boson line with fermion line.

We are currently attempting to develop an algebraic superfield formalism for this idea. Each constitutent field carries a pair of ordered indices, with the Lagrangian a trace of products of fields in conformity with Figs. 1(c) and 2(c). The electroweak boson field is a bispinor ${}_iA_j(x)$ with each index 8 valued--a Dirac 4-spinor $\times$ a Pauli 2-electrospinor. The lepton and antilepton fields ${}_i\psi_\ell(x)$ and ${}_\ell\overline{\psi}_i(x)$, have a similar 8-valued fermion index i, while the 4-valued bosonic index ℓ remains unaffected by Lorentz transformations. The Lorentz-

transforming spin $-$ 1/2 degree of freedom is present on the fermion line but not on the boson line. Because the remaining pair of 2-valued orientations are shared by boson and fermion indices, we hope for cancellation of closed-loop electroweak divergences through matching of fermion loops against boson loops, as in Fig. 3.

Although scalar fields accompany vector fields in topological theory, the massless "supersymmetry" is not broken "spontaneously" by a Higgs mechanism at the purely-electroweak level. Reference (10) shows instead how hadron-electroweak boson coupling breaks both electrospin and parity symmetry. Such symmetry breaking is "soft" because, as already remarked, the contractibility of elementary hadrons renders their interactions "nonlocal" in space-time. Reference (9) explains the phenomenological connection between topological theory and the standard electroweak model.[8]

The symmetry-breaking mass scale is provided by the nonvanishing elementary-hadron mass m_0, showed by Stapp to be required by chiral consistency at the lowest level of the topological expansion.[6] This base level, called "zero entropy", is controlled by the coordinated contraction of lines and vertices in Feynman graphs[5] and requires a unit matrix in the Dirac space of each hadronic fermion ("quark") line;[2] a non-vanishing elementary-hadron mass is thus implied. Dimensionless combinatoric factors (discussion below of coupling constants gives examples) are available to spread out the physical mass spectrum of poles which develop when the topological expansion is summed to infinite order.[F2]

Until a complete set of Feynman rules has been achieved, the foregoing remains only a scenario, but the recent development of rules for the purely hadronic sector[2] justifies optimism. The grand scenario of topological particle theory includes two coupling-constant considerations discussed in earlier papers which we mention now for completeness. (1) The elementary electroweak coupling constant e_0 has been conjectured to derive its value from the elementary-hadron coupling constant g_0[11] which emerges from the zero-entropy bootstrap with the order of magnitude

$$\frac{g_0^2}{4\pi} \sim \frac{4\pi}{(32)^2} \sim 10^{-2},$$

the number 32 being the total "quark"-line multiplicity: 2 spins × 2 chiralities × 2 electrospins × 4 generations.[11,12,13] (2) The large magnitude of physical hadron coupling constants derives from the combinatorics of "quark" chirality and "color".[14,15] [Topological "color"[5] describes permutations of fermion-line ends within hadrons. See Fig. 2(a,b).] These topological degrees of freedom are summed for hadrons but not for nonhadrons, so the physical value of the unit electric charge remains of order g_0.

In topological theory strong and electroweak interactions have interdependent, even though nonparallel, status. Reference (11) argued that unitarity, in conjunction with a topological expansion, requires electroweak bosons as well as hadrons. The proposal of the present paper is that unitarity further requires leptons to complement electroweak bosons; otherwise "hard" boson vertices lead to divergences inadmissible in a topological expansion. The number of lepton generations must match electroweak-boson multiplicity; at the present time it appears (although presumably it is not) accidental that this number is the same as the number of quark generations.

Acknowledgment

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. We also acknowledge useful discussions with B. Nicolescu and V. Poénaru. Part of the work was carried out at the Laboratoire de Physique Théorique des Particules Élémentaires, Université Pierre et Marie Curie. Two of the authors (G.F.C. and D.I.) express gratitude to R. Vinh Mau for extending the hospitality of his laboratory.

Footnotes

(F1) Our boson number b might also be called "hypercharge". Because b = L − B, boson number according to Ref. (7) gives the difference between electric charge and the third component of electrospin. Although the quantum-number table of Ref. (7) requires revision to accord with the present paper, there is no change in the meaning of electrospin.

(F2) Because leptons couple to hadrons only indirectly--via electroweak bosons--it is not surprising that some physical lepton masses occupy low positions in the spectrum.

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Figure Captions

1. Solid lines are Feynman lines; dashed lines are fermion lines.

   (a) Three mesons;

   (b) Three mesons, one electroweak boson;

   (c) Three electroweak bosons.

2. Hatched lines are boson lines.

   (a) Meson, baryon, antibaryon;

   (b) Electroweak boson, baryon, antibaryon;

   (c) Electroweak boson, lepton, antilepton.

3. A fermion loop and a boson loop.

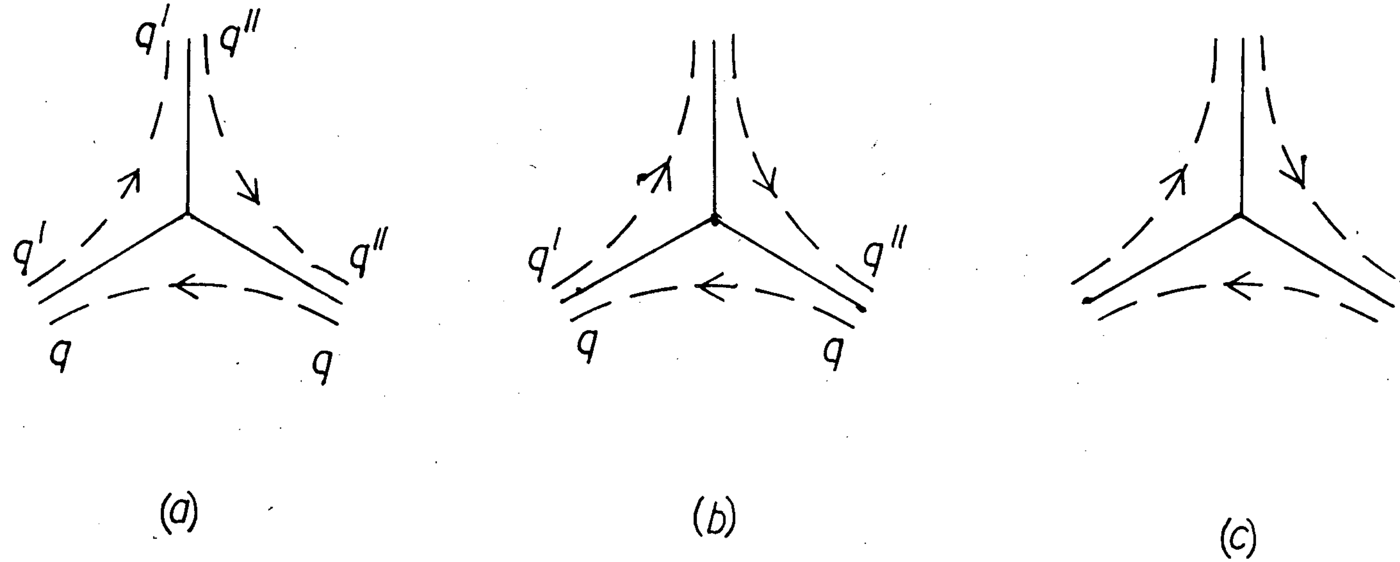

Figure 1

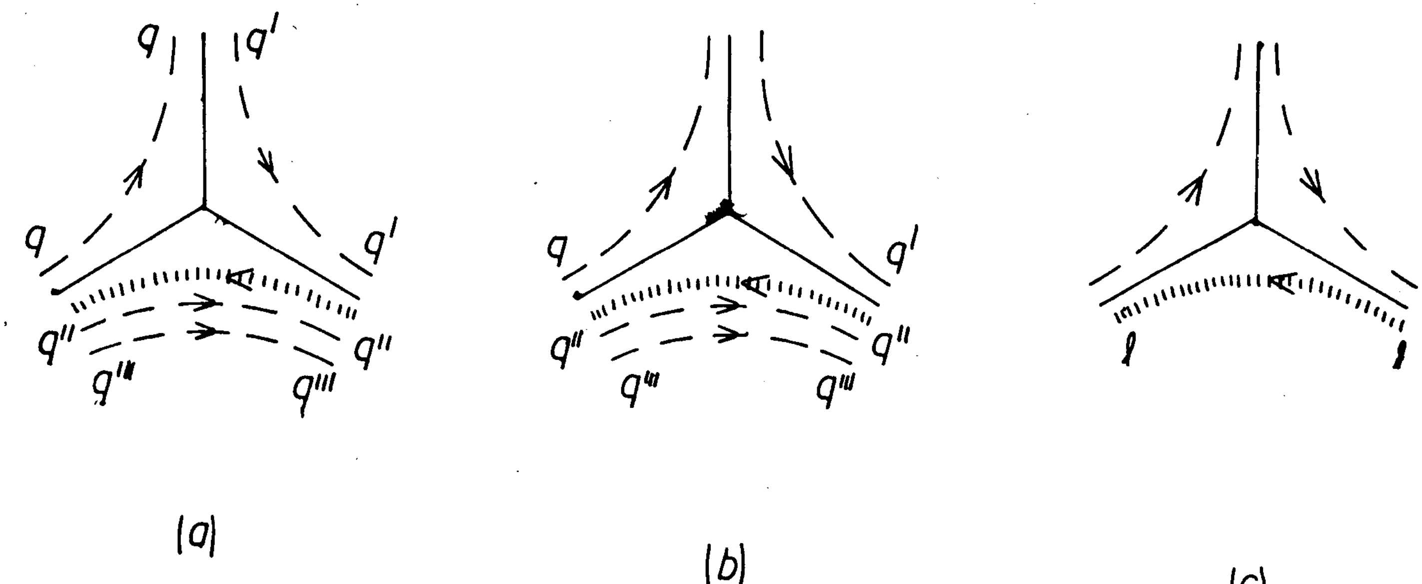

Figure 2

Figure 3

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