Title

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Publication Date

1985

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UNIVERSITY OF CALIFORNIA

Physics Division

Submitted for publication

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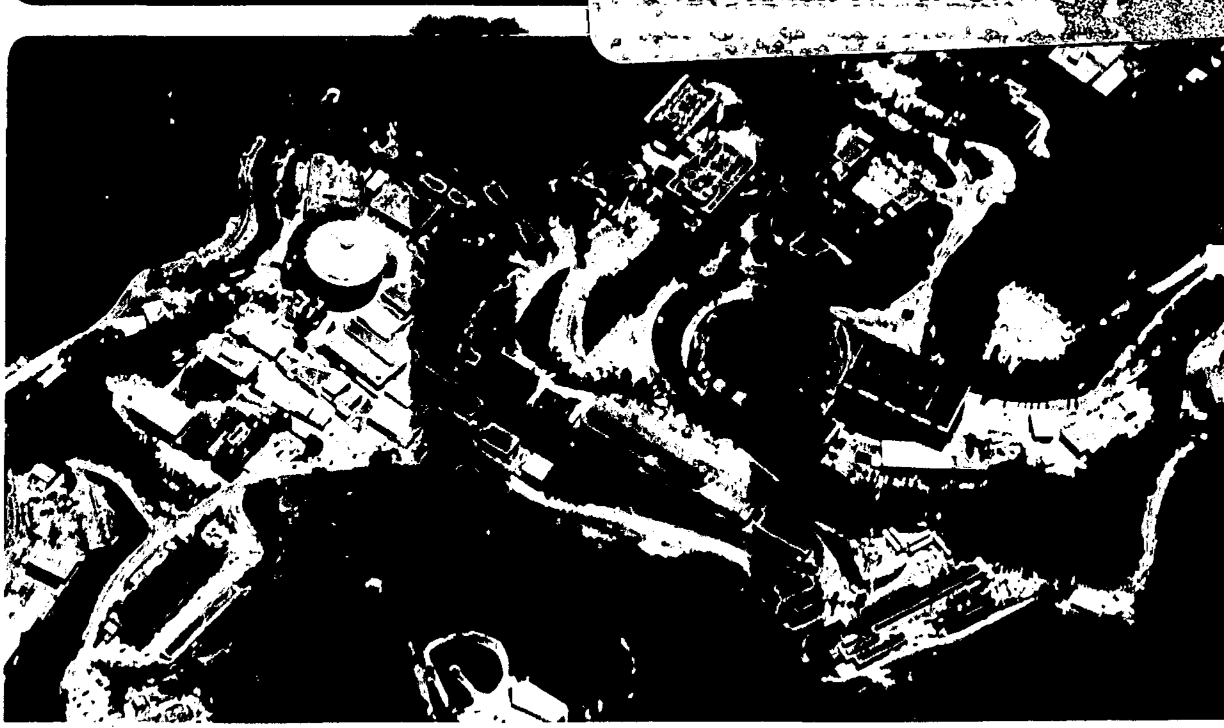

Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

January 1985 LBL-19002

LEPTONS AND "HORIZONTAL" NEUTRAL SCALAR BOSONS FROM TOPOLOGICAL BOOTSTRAP THEORY

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Abstract

The 8 "gauge" vector bosons of topological bootstrap theory are accompanied by a 4-generation--$\ell = 1,2,3,4$ -- family of isodoublet Dirac leptons -- and 8 neutral-scalar off-diagonal "horizontal" bosons $H_{\ell\ell'}$-- H_{12}, H_{13}, H_{24}, H_{34} plus conjugates -- in a nonhadronic massless elementary multiplet. Physical nonhadron masses are generated by interaction with a hadron supermultiplet (spins 0, 1/2, 1, 3/2, 2) whose scale-setting elementary mass lies in the TeV range. A single small dimensionless coupling constant e_0 controls all nonhadron interactions. All gauge and H bosons and the $\ell=4$ charged lepton, which we call λ, couple directly to hadrons and (except for the photon) thereby acquire masses large on the GeV scale. The 3 remaining charged leptons acquire masses indirectly -- such that m_2 and m_3 are of order $e_0^2 m_4$ and

This work was supported 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.

m_1 is of order $e_0^4 m_4$. We identify $\ell=1$ with the electron and $\ell=2$, 3 with μ and τ. The mass m_λ of the $\ell=4$ charged lepton is estimated to be of order 1 TeV, and H masses are believed to have a similar order of magnitude. Each neutrino mass is of order $e_0^2 \theta_\chi$ times the mass of its charged partner, where θ_χ is the mixing angle between right and left-handed W bosons; there is no neutrino mixing.

Topological bootstrap theory associates all particle properties except momentum with orientations of one- and two-dimensional manifolds which embellish Feynman graphs.[1] A unique supermultiplet of massive elementary hadrons has been deduced[2] with a scale-setting elementary mass m_0 which has been inferred to lie in the TeV range.[3] Extension of the theory to achieve classical measurement via massless photons coupled to a conserved charge has led, using those embellishments already required by hadrons, to a family of 8 elementary massless "gauge" vector bosons, 7 of which acquire mass via direct interaction with hadrons.[4] The phenomenological content of the standard electroweak model[5] has been recognized as embedded within this pattern. This letter reviews in algebraic language how those embellishments needed for hadrons <u>further</u> lead to a unique family of elementary massless Dirac leptons as well as a neutral scalar family of "horizontal" bosons. We achieve qualitative understanding of the observed lepton mass spectrum and predict the mass of a 4th charged lepton. Algebra will suffice to express most of topological theory's nonhadron rules, even though some rules will sound arbitrary. Topological language -- needed for full illumination -- will be employed elsewhere in a more complete paper.[6]

Algebraically speaking, any elementary particle in topological bootstrap theory corresponds to an ordered 2-index structure $\phi_{\beta\alpha}(p)$ with all properties <u>except momentum</u> residing in a right index α together with a left index β. Each of these indices depicts a set of reversible (2-valued) orientations and each index <u>separately</u> may be either fermionic or bosonic.

For nonhadrons a fermionic index takes 8 values, depicting three orientations -- one corresponding to spin $\binom{\uparrow}{\downarrow}_f$, one corresponding to chirality $\binom{0}{P}_f$, and one corresponding to isospin $\binom{c}{n}_f$. The spin-chiral content is that of a Dirac 4-spinor; spin and chiral fermionic orientations are not conserved--coupling to momentum and to each other in accord with Lorentz invariance. The isospin orientation <u>is</u> conserved and relates to electric charge. A right (left) fermionic index with c orientation carries $+1(-1)$ charge; with n orientation the charge is zero.

A nonhadron bosonic index is 4-valued; it lacks isospin content (being electrically neutral) but depicts two reversible orientations $\binom{\uparrow}{\downarrow}_b$ and $\binom{0}{P}_b$. These bosonic orientations do not couple to momentum and are preserved throughout all interactions. They lead to conserved internal quantum numbers that we shall call "lepton numbers" L_ℓ according to Table I. A bosonic right (left) index with orientations ℓ carries $L_\ell = +1(-1)$.

TABLE I

ℓ	Bosonic orientations
1	$(\downarrow)_b$ $(0)_b$
2	$(\downarrow)_b$ $(P)_b$
3	$(\uparrow)_b$ $(P)_b$
4	$(\uparrow)_b$ $(0)_b$

We draw attention to the fact that separate conservation of each L_ℓ forbids lepton mixing and decays such as $\mu^- \rightarrow e^-e^+e^-$. Furthermore, because hadrons in this theory have all four L_ℓ equal to zero, semileptonic transitions such as $K^0 \rightarrow e^+\mu^-$ or $e^-\mu^+$ are also strictly forbidden.

An elementary lepton (antilepton) has a bosonic right (left) index and a fermionic left (right) index. Fermionic spin and chirality are correlated in the usual way (according to the Dirac equation), so the leptonic content of bootstrap theory in standard language is that of Dirac (not Majorana) charged-neutral isodoublets in 4 generations.[7]

Elementary vector "gauge" bosons -- combining two fermionic indices -- have been described earlier.[4] The remaining combination is two bosonic indices -- to form a "horizontal" neutral scalar boson $H_{\ell\ell'}$ (p) with $L_\ell = -1$ and $L_{\ell'} = +1$.

All nonhadronic bosons have opposite $\binom{0}{P}$ orientations for their two indices. For gauge bosons the two possibilities 0P and P0 correspond to left-handed (L) versus right-handed (R) (e.g., the standard W_L is 0P). There is no parity significance for the $\binom{0}{P}$ content of a bosonic index but Table I shows that 0, P opposition means only 8 H's occur: H_{12}, H_{13}, H_{24}, H_{34} plus conjugates, each capable of coupling to lepton-antilepton pairs of different generation but same charge. Purely-hadronic or purely-nonhadronic couplings generally pair left-right indices that are both fermionic or both bosonic. Thus H bosons do not couple (directly) to gauge bosons.

Purely-nonhadronic Feynman vertices that couple "gauge" bosons via fermionic indices and those that couple H bosons via bosonic indices separately exhibit symmetries which are isomorphic--acting in both

cases on spaces built from the direct product of two equivalent 2-dimensional internal vectors:

$$\binom{c}{n}_{f(L)} \times \binom{c}{n}_{f(R)} \quad \text{- fermionic (chiral isospin)}$$

and (1)

$$\binom{\uparrow}{\downarrow}_{b(0)} \times \binom{\uparrow}{\downarrow}_{b(P)} \quad \text{- bosonic}$$

It further turns out that all purely-nonhadronic coupling constants are dimensionless. Although the symmetric status of fermionic and bosonic indices in the nonhadronic sector has not yet been translated into a standard supersymmetry algebra, it seems natural to infer not only masslessness of all elementary nonhadrons but a single bare dimensionless coupling constant e_0 for all purely-nonhadronic interactions.

Nonhadronic bosons interact directly with hadrons--the concomitant symmetry breaking[9] sparing only CPT and the conservation of electric charge, baryon number and lepton-generation numbers. Except for the photon all non-hadronic bosons acquire substantial masses and radii of order $m_0{}^{-1}$. The latter provides an effective cutoff in nonhadronic loops. Boson masses can approach the m_0 scale -- despite the smallness of elementary coupling constants -- because of the very high multiplicity of elementary hadrons.[10]

We now explain how leading components of the topological expansion generate a physical lepton mass spectrum similar to that observed. A key preliminary consideration is that the bosonic indices of elementary hadrons have no degrees of freedom belonging to $\binom{c}{n}_b$, $\binom{\uparrow}{\downarrow}_b$ or $\binom{0}{P}_b$ orientations. For hadrons these orientations are frozen at c, ↑ and 0. The consequence is that direct lepton-hadron interaction occurs only for charged leptons of the $\ell = 4$ generation (see Table I).[11] Reference (6) will discuss this interaction in detail. Here we merely denote by m_4 the charged-lepton mass delivered by direct hadron interaction and note that m_4 is expected a priori to have an m_0 order of magnitude. (In principle m_4 is calculable from m_0).

Figure 1(a) in conjunction with Table I shows how an H-boson loop indirectly generates mass of order $e_0^2 m_4$ for $\ell = 2, 3$ charged leptons but no mass to this order for $\ell = 1$. Mass for $\ell = 1$ is even less direct, requiring 2 loops, as shown in Fig. 1(b). Thus the ratios m_2/m_4, m_3/m_4, m_1/m_2, m_1/m_3 are all expected to be of order e_0^2.

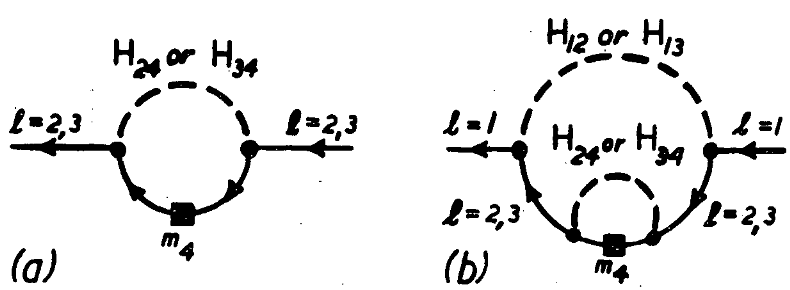

Fig. 1. Indirect lepton mass generation, starting from m_4.

The loops of Fig. 1 without cutoff are logarithmically divergent but Ref. (6) will show how all H bosons are expected to get masses on the m_0 scale from direct hadron interaction and to acquire m_0^{-1} "radii". The simple order of magnitude estimates thereby are supported and we are led to assign the electron to $\ell = 1$ and μ, τ to $\ell = 2, 3$.

Figure 1 does not explain the observed difference between μ and τ masses but, on a logarithmic scale, this difference is substantially smaller than the μ-e difference. Reference (6) will discuss a candidate mechanism for the μ-τ difference which involves an anomalous elementary particle -- neither hadron nor nonhadron--with vacuum quantum numbers, that has been predicted by topological bootstrap theory.[1]

In the present absence of understanding of the μ-τ mass difference we can guess the mass m_4 by assuming Fig. 1a to yield the geometric mean of observed μ and τ masses. Then

$$q \equiv \frac{m_e}{2(m_\mu m_\tau)^{\frac{1}{2}}} \approx \frac{(m_\mu m_\tau)^{\frac{1}{2}}}{m_4}, \qquad (2)$$

so we guess

$$m_\lambda \approx \frac{2 m_\mu m_\tau}{m_e} \approx 1\,\text{TeV}. \qquad (3)$$

Calculations to improve this estimate are in progress.

We round off our picture with remarks on neutrino masses. Already emphasized has been the absence of neutrino mixing. Chiral symmetry breaking, on the other hand, is not only unavoidable but can in principle be calculated, although presently we are not clever enough to do so. The 4 neutrino masses resulting from chiral-symmetry breakdown will eventually provide a test for the theory. Figure 2 shows the lowest-order hadronic and nonhadronic contributions to mixing between W_L and W_R. In what follows a mixing angle θ_χ characterizes this effect.

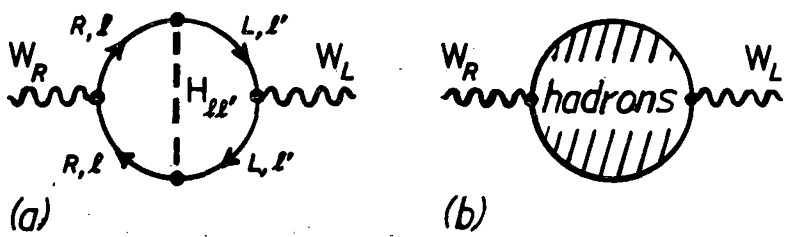

Fig. 2. Contributions to the mixing between W_L and W_R:

a) Lowest-order nonhadronic graph.

b) Hadronic contribution.

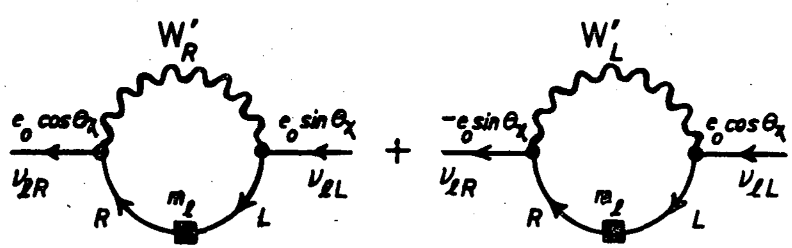

Fig. 3. Neutrino mass generation from charged-lepton mass, via mixed W_L', W_R'.

While neutrinos do not acquire mass through the Higgs mechanism (not coupling directly to any scalar with zero quantum numbers), the W loops of Fig. 3 generate neutrino masses indirectly from charged-lepton masses. Once neutrinos have thus acquired a small mass, the mechanism of Fig. 1 becomes operative as well. A rough estimate yields

$$m_{\nu_\lambda} \approx r\, m_\lambda \tag{4}$$

where

$$r \equiv \frac{\alpha_0}{\pi}\,\theta_\chi\,\ell n\frac{M_R^2}{M_L^2}, \tag{5}$$

and, remembering Formula (2), we also obtain

$$\begin{aligned} m_{\nu_{\tau,\mu}} &\approx r(m_\mu m_\tau)^{1/2} + q m_{\nu_\lambda} \approx 2r(m_\mu m_\tau)^{1/2} \\ m_{\nu_e} &\approx r m_e + 2q m_{\nu_{\mu,\tau}} \approx 2\, r m_e . \end{aligned} \tag{6}$$

From the present upper bound $m_{\nu_e} < 40$ eV, we conclude that $r < 4 \times 10^{-5}$ and if, further, $M_R > 6M_L$,[12] we infer that $\theta_\chi < 10^{-3}$.

ACKNOWLEDGMENTS

Discussions with S. Dawson, I. Hinchliffe, B. Nicolescu, V. Poénaru, M. Suzuki, and L. Wolfenstein have been helpful to this paper. The contribution of J. Finkelstein has been crucial, not only in encouraging us to pursue horizontal scalar bosons but in clarifying detailed properties of these particles. The present paper is a direct outgrowth of an unpublished collaboration (Ref. (7)) with Finkelstein. This work was supported 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.

FOOTNOTES AND REFERENCES

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8. H bosons were first recognized by G. F. Chew, J. Finkelstein, B. Nicolescu and V. Poénaru, *Zeit. f. Phys.* C14, 289 (1982).
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10. G. F.Chew, *Phys. Rev. Lett.* 47, 764 (1981).

11. The possibility of this lepton-hadron interaction does not mean that some hadrons have $L_\ell \neq 0$, even though their bosonic index takes the same value as for λ-leptons. Lepton numbers L_ℓ and baryon number B are linear combinations of five absolutely conserved quantities: fermion number f and four boson numbers b_ℓ.[7]

$$B = \tfrac{1}{2}(f + \sum_{\ell=1}^{4} b_\ell),$$

$$L_\ell = b_\ell + \delta_{\ell 4} B.$$

All nonhadrons have $B = 0$ while for all hadrons $L_\ell = 0$. For baryons one finds $f = 3, b_4 = -1$, with $b_1 = b_2 = b_3 = 0$.

12. J. Carr et al., *Phys. Rev. Lett.* 51, *627 (1983)* and preprint LBL-18935 (1984), submitted to *Phys. Rev. Letters*.

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