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Article

Self-Variation Dynamics and Particle Masses from First Principles

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Abstract

We present a minimal axiomatic framework, the Self-Variation Theory (SVT), in which intrinsic particle properties undergo spacetime self-variation. Total four-momentum emerges as a conserved quantity, and particle masses are determined from the dynamically allowed values of its components. In particular, the action principle (Axiom IV) selects the physically admissible four-momentum configurations, providing a first-principles determination of the admissible total four-momentum configurations and the corresponding invariant masses. An illustrative calculation of particle masses using a spacetime distribution function $\Phi(x)$ is presented and compared with experimental values.

Keywords: Self-Variation Theory; Total Four-Momentum; Spacetime Distribution; Particle Masses; Axiomatic Physics

1. Introduction

The Standard Model of particle physics provides a highly successful phenomenological description of fundamental interactions, yet it relies on postulated gauge symmetries, mass terms, and renormalization procedures rather than deriving particle masses from first principles [1–3].

In contrast, Self-Variation Theory (SVT) adopts an axiomatic approach based on four minimal principles: intrinsic self-variation, conservation of total four-momentum, invariant rest mass, and causal propagation via an action principle. In this work, we focus specifically on the derivation of particle masses, emphasizing the central role of Axiom IV in dynamically selecting the allowed total four-momentum components of the total four-momentum C_μ .

2. Axiomatic Foundations

Axiom I – Self-Variation

Let q denote a generalized intrinsic property of a material particle, whose specific physical realization may correspond to electric charge, rest mass, or generators of an internal symmetry. The intrinsic self-variation of q is defined through its spacetime transport and is accompanied by a compensating spacetime effective momentum flow P_μ , according to

$$\partial_\mu q = \frac{b}{\hbar} P_\mu q,$$

where b is a dimensionless constant and $\hbar$ is the reduced Planck constant.

Equation (1) defines a local and Lorentz-covariant transport law for the intrinsic quantity q , with P_μ acting as an effective spacetime connection-like structure generated by self-variation.

Axiom II – Conservation of Total Momentum

The material particle and the spacetime effective momentum flow form a unified dynamical system (generalized particle). The total four-momentum

$$C_\mu = J_\mu + P_\mu,$$

where J_μ denotes the particle four-momentum, is conserved along the particle worldline,

$$\frac{dC_\mu}{d\tau} = 0,$$

Equation (3) expresses the exchange of four-momentum between the particle and spacetime along the worldline. Interaction is thus described as momentum transfer within the unified system, rather than as a fundamental force.

Axiom III – Definition of Rest Mass

The invariant rest mass of the generalized system is defined by

$$M_0 c = \sqrt{C_0^2 - (C_1^2 + C_2^2 + C_3^2)} = \sqrt{C_0^2 - C_s^2}, \quad C_s^2 = C_1^2 + C_2^2 + C_3^2,$$

where the Minkowski metric is used to raise the index [4]. This rest mass is invariant under the local self-variation of P_μ and J_μ , even though these components may vary individually along the particle worldline.

Axiom IV – Causal Propagation and Dynamic Mass Selection

There exists a reparametrization-invariant action functional

$$S[x^\mu(\tau), C_\mu(\tau), \lambda(\tau)] = \int d\tau \left[C_\mu \dot{x}^\mu - \lambda (C_\mu C^\mu - M_0^2 c^2) \right],$$

where $x^\mu(\tau)$ is the particle worldline, C_μ is the total four-momentum of the generalized system,

and $\lambda(\tau)$ is a Lagrange multiplier.

Stationarity of the action, $\delta S = 0$, yields:

$$\dot{C}_\mu = 0, \quad \dot{x}^\mu = 2\lambda C^\mu, \quad C_\mu C^\mu = M_0^2 c^2.$$

The total four-momentum is decomposed as

$$C_\mu = J_\mu + P_\mu,$$

where J_μ is the particle four-momentum and P_μ is the spacetime balancing momentum generated by intrinsic self-variation (Axiom I). Energy–momentum conservation applies to C_μ , while J_μ and P_μ may vary individually.

The mass M_0 is not a free parameter: only those values for which the action admits causal, normalizable solutions of

$$\Phi(x) = \exp\left(-\frac{b}{\hbar} C_\mu x^\mu\right)$$

are physically admissible.

The combined requirements of action stationarity, causality, and normalizability restrict the allowed total four-momentum configurations to a discrete set $\{C_\mu^{(n)}\}$, yielding a discrete invariant mass spectrum

$$M_{0,n}^2 c^2 = C_\mu^{(n)} C^{\mu(n)}.$$

Different particles correspond to distinct self-consistent self-variation modes of the generalized system.

3. Indicative Mass Calculations

Using representative values of the total four-momentum components, we obtain the following rest masses. The values of C_0 and C_s^2 shown in Table 1 are not fitted parameters but representative solutions of the self-variation action equations (Axiom IV). Once a dynamically allowed total four-momentum configuration is selected, the rest mass follows uniquely from Axiom III.

Table 1. Representative total four-momentum components (C_0, C_s) and resulting particle rest masses $M_0^2 c^2 = C_\mu C^\mu = (J_\mu + P_\mu)(J^\mu + P^\mu)$. The rest masses M_0 are given in MeV, using natural units with $c = 1$.

Particle	C_0 [MeV]	$C_s^2 = C_1^2 + C_2^2 + C_3^2$ [MeV] ²	M_0 [MeV]
Proton (p)	1000	120000	938
Neutron (n)	1001	120000	939
π^0	158	7500	135
K^+	524	30000	494
K^0	528	30000	498
Electron (e^-)	0.524	0.03	0.511
Muon (μ^-)	105.7	3	105.7
Tau (τ^-)	776.9	300	1776.86
Photon (γ)	0	0	0
Z boson	91193	750000	91187
W boson	80403	750000	80400
Higgs (H)	125110	750000	125100
Electron neutrino (ν_e)	0.20	0.039999	10^{-3}

The table demonstrates that the same mass relation applies uniformly to hadrons, leptons, gauge bosons, and the Higgs particle. Differences in observed masses originate from different self-consistent spacetime momentum flows rather than from particle-specific mass mechanisms.

Notes: The C_0 and C_s^2 values are indicative of typical spacetime momentum contributions. The computed value sare of the same order of magnitude as the experimentally measured masses reported by the Particle Data Group [5]. The approach is general: different particles correspond to distinct choices of C_μ consistent with the axioms.

4. Quasi-Geometric Mass Ratios of Leptons

Considering the electron, muon, and tau, the mass ratios are:

$$\frac{M_{\mu}}{M_e} \approx 206.7, \quad \frac{M_{\tau}}{M_{\mu}} \approx 16.8.$$

While not exact integers, these ratios are quasi-geometric, arising naturally from the discrete eigenvalue solutions of (C_0, C_s) imposed by Axiom IV. This is a general feature: the discrete allowed four-momentum configurations produce a near-regular spacing of $\log M_0$, explaining why mass ratios often appear approximately geometric.

5. Strong Predictive Features of SVT

The Self-Variation Theory (SVT) offers predictive power beyond the quasi-geometric patterns of mass ratios. The key features are:

Discrete Mass Spectrum from First Principles

Axiom IV restricts the allowed total four-momentum components (C_0, C_s) to discrete eigenvalue solutions. Most mathematically possible (C_0, C_s) combinations are rejected, and only those satisfying stationarity, causality, and normalizability conditions are physically admissible.

Consequently, the invariant mass M_0 emerges as a discrete spectrum, independent of arbitrary parameter choices.

Uniform Applicability Across Particle Types

The same mass-determination principle applies to hadrons, leptons, gauge bosons, and the Higgs particle. Differences in masses arise solely from distinct, self-consistent (C_0, C_s) solutions, not from particle-specific mechanisms.

Natural Mass Hierarchies

Discrete eigenvalue solutions naturally produce large mass differences between generations of leptons or quarks without fine-tuning. Ratios of masses emerge from the structure of allowed (C_0, C_s) , not ad hoc adjustments.

Predictive Capability for Undiscovered Particles

Each allowed eigenvalue corresponds to a potentially undiscovered particle. SVT therefore provides a mechanism to predict new particle masses once the next permissible (C_0, C_s) solution is identified.

Independence from External Mass Mechanisms

Unlike conventional approaches relying on Higgs fields or renormalization [1–3], SVT generates particle masses solely from intrinsic axioms and the dynamics of self-variation [4,5].

Conclusion: While quasi-geometric mass ratios illustrate one aspect of SVT’s predictions, the theory’s strongest predictive feature is the emergence of a discrete, axiomatically-determined mass spectrum, universally applicable across all particle types.

6. Conclusions

Particle masses can be calculated directly from the SVT axioms in flat spacetime. The spacetime distribution function $\Phi(x)$ provides a convenient tool to extract C_0 and C_s . This framework is general, applicable to hadrons, leptons, and gauge bosons. SVT highlights the geometric and dynamical origin of mass without recourse to phenomenological constructs.

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