The Theory of Isomorphic Physics

Part 6: Particle Interactions and the Standard Model

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The Standard Model

The previous paper in this series might qualitatively be described as a rework of quantum mechanics and have lead to equations relatively well-grounded in canonical physics. From this paper forward, we explore an extension of quantum mechanics using a non-quantum field theory (QFT) framework, aiming to establish connections to the Standard Model's structure through unique algebraic and category-theoretic foundations. Quantum mechanics, while deeply integrated into the Standard Model, is typically extended to particle interactions and symmetries through QFT. By contrast, the approach developed here reworks foundational quantum mechanics equations and introduces a novel algebra to represent particle states and transformations. This framework allows for unique reinterpretations of particle interactions—such as those associated with the weak force—by leveraging the symmetry properties of categories and morphisms within the algebra. Given that a non-QFT-based approach to the Standard Model is relatively uncharted, this paper positions these interpretations as speculative extensions, exploring how the category-theoretic structure of this theory might imply transformations that mirror the dynamics of particle interactions. We introduce this speculative framework to propose that certain aspects of the Standard Model's structure could emerge from quantum mechanics alone, challenging the prevailing reliance on QFT and suggesting new possibilities for interpreting particle symmetries and interactions.

Interactions

In this framework, interactions between particles are governed by their compatibility in forming a new composite state. When two particle states, α_1 and α_2, interact, they have the potential to combine or "glue" together to form a new composite particle:

$$|\alpha_1\alpha_2) = |\alpha_3)$$

In this case, α_1 and α_2 combine to form α_3, representing the creation of a new particle state from their interaction. The probability of such "gluing" interactions, resulting in a transformation, is represented by:

$$P_{\text{interaction}} = (\alpha_1\alpha_2|\alpha_1\alpha_2)$$

This probability quantifies the likelihood that α_1 and α_2 will successfully interact to form the composite state α_3.

Connections to Quantum Field Theory Interaction Terms

The approach of multiplying particle states in this theory to evaluate the probability of interaction loosely resembles the interaction terms found in quantum field theory (QFT). In QFT, interaction terms involve the multiplication of field operators, representing different particles, to compute the probability amplitude of their interaction or scattering. Though this current theory aligns more closely with the formalism of quantum mechanics, the idea of multiplying states to represent interactions has some parallels with QFT.

In QFT, fields are treated as operator-valued distributions, and interactions are expressed as products of field operators at the same spacetime point. Similarly, in this framework, the interaction between particles is represented by the product of the states, reflecting the overlap of the two particle states at a given position. This overlap signifies the conditions necessary for an interaction to occur, much like how field operators in QFT describe the interaction probability at a specific location.

Thus, while the theoretical framework here diverges from QFT in many ways, the treatment of interaction probabilities through the multiplication of states offers a familiar conceptual structure that mirrors the field-theoretic interaction approach in some respects.

Statistical Interpretation of Interaction Probability

At a more intuitive level, the multiplication of particle states to determine the probability of interaction can be understood through statistical reasoning. In probability theory, the probability of two independent events occurring simultaneously is given by the product of their individual probabilities. Similarly, in this theory, multiplying the two particle states can be seen as determining the joint probability of both particles existing in the same region of space, where they can interact.

This joint probability provides a statistical basis for calculating the likelihood that two particles will interact and fuse into a new particle. The interaction is contingent upon both particles being found within the same spatial region, which is effectively represented by multiplying their states together to account for the overlap in their spatial and physical properties. The resulting probability is proportional to the likelihood of interaction, aligning with the principles of probability theory in which the occurrence of simultaneous events is captured through multiplication.

This analogy with statistics supports the use of multiplication in calculating interaction probabilities, providing both a mathematical and intuitive basis for the approach.

Implications for Interaction Dynamics

The use of state multiplication to represent interactions provides a simple yet powerful framework for describing particle fusion or annihilation. The overlap between particle states encapsulates the physical conditions necessary for interaction, including spatial proximity and charge compatibility. By relating these conditions to probabilities, the framework ensures that interactions are treated in a consistent manner with both quantum mechanics and statistical reasoning, reinforcing the validity of the proposed interaction mechanism.

Furthermore, this formulation may offer insight into the underlying principles of particle interactions in other areas of physics, such as quantum field theory, by highlighting the significance of spatial overlap and charge compatibility in governing interaction outcomes.

1 Combining Hamiltonians for Interacting States

Having defined the Hamiltonian relationship for each independent particle state, we can begin to explore the implications of combining these states within this theoretical framework. Each state α_1, α_2, and their product state $\alpha_3 = \alpha_1\alpha_2$, satisfies the following balance condition:

$$T + V - H = 0 \tag{1}$$

which is expressed for each individual state as:

$$\left(\alpha_s\middle|\hat{P}\middle|\alpha_s\right) - \left(\alpha_t\middle|\hat{E}\middle|\alpha_t\right) = 0 \tag{2}$$

This framework allows us to examine how energy, momentum, and mass rates combine in the product state α_3 when states α_1 and α_2 interact.

1.1 Individual Balance Conditions for Non-Interacting States

For the independent states α_1 and α_2, we have:

$$\left(\alpha_{s1}\middle|\hat{P}\middle|\alpha_{s1}\right) - \left(\alpha_{t1}\middle|\hat{E}\middle|\alpha_{t1}\right) = 0 \tag{3}$$

$$\left(\alpha_{s2}\middle|\hat{P}\middle|\alpha_{s2}\right) - \left(\alpha_{t2}\middle|\hat{E}\middle|\alpha_{t2}\right) = 0 \tag{4}$$

These equations imply that each particle state independently satisfies its Hamiltonian dynamics in the absence of interaction.

1.2 Combined Hamiltonian of Interacting States

For the combined state $\alpha_3 = \alpha_1\alpha_2$, the Hamiltonian relationship is given by:

$$\left(\alpha_{s3}\middle|\hat{P}\middle|\alpha_{s3}\right) - \left(\alpha_{t3}\middle|\hat{E}\middle|\alpha_{t3}\right) = 0 \tag{5}$$

where α_{s3} and α_{t3} are defined as the spatial and temporal components of the product state. This combined Hamiltonian incorporates contributions from both α_1 and α_2, suggesting that the combined energy, momentum, and mass rates can be understood as a natural extension of the theory to include nonlinear or interacting dynamics.

1.3 Interaction Terms and Non-Zero Hamiltonian Balance

In scenarios involving interactions, it may be necessary to introduce an interaction term that modifies the balance condition for α_3 such that:

$$\left(\alpha_{s3}\middle|\hat{P}\middle|\alpha_{s3}\right) - \left(\alpha_{t3}\middle|\hat{E}\middle|\alpha_{t3}\right) \neq 0 \tag{6}$$

This interaction term could model cases where the total energy is no longer conserved, leading to the possibility of energy transfer between the interacting states. Such a modification may provide insight into interactions that go beyond the zero-energy balance of the system.

1.4 Statistical Interpretation of Combined States

The probability of interaction could be linked to the overlap of the Hamiltonian states, with the statistical framework providing insights into the likelihood of specific interaction outcomes. By exploring the overlap integrals of combined Hamiltonian states, we may derive probabilistic predictions for interactions, grounded in the balance conditions of energy, momentum, and mass.

This approach, based on combining Hamiltonian dynamics across interacting states, offers a method to unify the energy, momentum, and mass rates within the algebraic framework, potentially offering new perspectives on interaction dynamics.

2 Category-Theoretic Bridge for Interacting States and Resultant Dynamics

In this framework, interactions between states α_1 and α_2 are mediated by a transition across categories, facilitated by the parentheses notation that combines these states. The resultant state α_3, formed as $\alpha_3 = \alpha_1\alpha_2$, represents a new object in a third category, distinct from those of α_1 and α_2.

2.1 Interacting Categories and the Transition Bridge

The probability of interaction between α_1 and α_2 is expressed by the object:

$$P_{\text{interaction}} = (\alpha_1\alpha_2|\alpha_1\alpha_2)$$

This probability, represented by the paren-theses notation, serves as a bridging object between categories. Here, α_1 and α_2 belong to distinct categories (such as two fermion states), and the resultant state α_3 belongs to a new category (e.g., a bosonic state). The probability of interaction object does not itself contain Hamiltonian information but instead facilitates the transition to the resultant state in the new category.

2.2 Resultant State Dynamics and Morphisms in the New Category

The transition to the resultant state α_3 marks the formation of a new category. Within this category, morphisms can then be applied to α_3 to retrieve its energy, momentum, and mass (Epm) state or position state. Unlike in the pre-interaction state where individual Epm states of α_1 and α_2 could be combined, the morphisms on α_3 as a single, unified state ensure that it satisfies the appropriate Hamiltonian dynamics. This distinction is crucial: applying morphisms to α_3 as a single object avoids the unwanted scaling behavior that would occur if we naively combined the Epm states of α_1 and α_2 directly.

2.3 Morphisms from the Resultant State to Epm and Position States

Once the transition to α_3 is complete, morphisms specific to the resultant category allow us to obtain the Epm and position states, each of which respects the appropriate Hamiltonian mechanics and Minkowski Spacetime (MST) conditions. For example:

$$\left(\alpha_{s3}\middle|\hat{P}\middle|\alpha_{s3}\right) - \left(\alpha_{t3}\middle|\hat{E}\middle|\alpha_{t3}\right) = 0$$

This equation shows the Hamiltonian object in the new category, which accurately captures the dynamics of α_3 as a single, composite entity. The Hamiltonian relation here is preserved under morphisms that act on α_3 directly, not on separate Epm states from the original α_1 and α_2.

2.4 Ensuring Consistency with Hamiltonian Mechanics Across Categories

The process outlined above maintains consistency with Hamiltonian mechanics by focusing morphisms on the resultant state α_3 rather than on individual components from α_1 and α_2. This ensures that energy, momentum, and mass do not exhibit scaling behaviors inconsistent with physical dynamics. In this sense, the bridging mechanism (the paren-theses notation) is essential: it creates a structured transition that allows each resulting category to have its own well-defined set of morphisms aligned with the unified Hamiltonian and position frameworks of the theory.

Thus, the transition through the bridging objects $(\alpha_1\alpha_2|\alpha_1\alpha_2)$ and α_3 maintains both the unique category characteristics of the resultant particle and the consistency required for correct Hamiltonian and positional dynamics.

Bosons as Objects in the Gauge Boson Category

In this theoretical framework, bosons are represented as objects within a specific category that we can associate with gauge bosons. The elements I, A, B, and C in the dualistic group represent distinct types of bosons that act as force carriers in interactions. Each bosonic object exhibits specific transformation properties, with morphisms that map to distinct boson types such as photons, W and Z bosons, and gluons.

- **General Bosons as Objects**: The objects I, A, B, and C represent different boson types within this gauge boson category. Each object carries a set of morphisms associated with unique transformation properties that resemble gauge bosons in the Standard Model.
- **Boson Objects with Specific Morphisms**: The morphisms within this category distinguish specific bosons like the photon, W, Z, and gluons:
  - I_γ: Represents the photon, an object with morphisms corresponding to electromagnetic interactions.
  - I_W, A_W, B_W, C_W: Represent objects for the W and Z bosons, with morphisms that define their role in mediating weak interactions.
  - I: An object representing neutral gluons, carrying morphisms associated with the 7th and 8th gluons in Quantum Chromodynamics (QCD). These objects mediate strong interactions without altering the net color charge.
- **Color-Charged Gluons as Objects with Color-Related Morphisms**: The elements A, B, and C are associated with gluons that carry color-anticolor charges. In this formalism, the morphisms represent transformations linked to quark color exchange:
  - A: Represents gluons with green and anti-blue or anti-green and blue color charges.
  - B: Represents gluons with red and anti-blue or anti-red and blue color charges.
  - C: Represents gluons with red and anti-green or anti-red and green color charges.

Each of these color-charged objects corresponds to non-neutral gluons, which participate in color exchange interactions. The specific morphisms associated with A, B, and C allow for transformations that mediate strong force interactions between quarks.

Bosonic objects in this category can interact to form composite structures. These interactions, governed by morphisms and subject to zero-equation properties, ensure that any combination or superposition of bosons adheres to the theory's symmetry and normalization constraints.

Fermions as Objects in the Matter Category

Fermions, represented by the elements G, X, Y, and Z, belong to the category of matter particles and are foundational in constructing composite matter states, such as leptons and quarks.

- **Leptons as Objects**: The object G represents leptons, particles such as electrons, neutrinos, and their antiparticles, which are color-neutral. Morphisms associated with G define transformations for different leptonic states:
  - G_e: Represents the electron, a specific object within the lepton subset.
  - G_ν: Represents the neutrino.
  - $G_{\bar{e}}$: Represents the positron, the electron's antiparticle.
- **Quarks as Objects with Color Charge Morphisms**: The elements X, Y, and Z represent quarks, which carry color charges and interact via the strong force. Morphisms within this subset define transformations for quarks with different color charges:
  - X: Represents quarks with red (and anti-red) color charges.
  - Y: Represents quarks with green (and anti-green) color charges.
  - Z: Represents quarks with blue (and anti-blue) color charges.

  These objects can combine through morphisms to construct composite states like baryons (protons and neutrons) or mesons. For instance:

  $$\alpha_p = X_u Y_u Z_d$$

  could represent a proton, where each morphism links the red, green, and blue charges of two up quarks (u) and one down quark (d), adhering to the color neutrality required for composite particles.

This category-based formalism allows both bosonic and fermionic objects to engage in interactions and transformations, governed by morphisms that adhere to symmetry requirements and fundamental constraints of the theory.

Fermion and Boson Interaction in the Category Framework

Within this theoretical framework, fermions and bosons interact as objects within distinct categories, where morphisms define their interactions. Fermions, represented by G, X, Y, and Z, interact with bosons, represented by I, A, B, and C. These interactions are governed by morphisms adhering to the symmetry and conservation rules intrinsic to the category structure of the algebra.

For example, the interaction of an electron with a photon might be represented as:

$$\alpha_{G_e}\alpha_{I_\gamma} = \alpha_{G_e}$$

This relation captures the concept that an electron can absorb or emit a photon without changing its fundamental fermionic nature, though it may alter its energy and momentum through the morphism associated with α_{I_γ}. Similarly, interactions between quarks and gluons involve morphisms that define the exchange of color charge:

$$\alpha_{X_u}\alpha_A = \alpha_{Y_u}$$

This transformation represents a red up quark interacting with a green-antiblue gluon, resulting in a green up quark, with the color exchange captured by morphisms within the quark-gluon interaction category.

Interaction Notation and Transformation Processes

This section describes interactions between fermions and bosons, as well as fermion-antifermion annihilation, through the algebraic structure of the group elements. Each interaction corresponds to a transformation process and is represented via algebraic multiplication. These interactions are analogous to processes in Feynman diagrams, where interaction outcomes are bosons or new fermions, depending on the context.

- $X_\mathrm{q} \cdot X_{\overline{\mathrm{q}}} = I_\gamma$:

  This equation represents a quark-antiquark annihilation, where a quark (X_q) and its corresponding antiquark ($X_{\overline{\mathrm{q}}}$) annihilate to form a photon (I_γ). This transformation corresponds to a fundamental morphism in the category, connecting fermionic states to bosonic outcomes.

  In Feynman notation: $\mathrm{q} + \overline{\mathrm{q}} \to \gamma$

  In category language, this process follows the rule that fermion-antifermion pairs transform into bosonic elements, preserving the interaction dynamics defined within the structure.

- $G_{e^-} \cdot G_{e^+} = I_\gamma$:

  Representing electron-positron annihilation, this equation shows how an electron (G_{e^-}) and a positron (G_{e^+}) transform into a photon (I_γ). This annihilation is a canonical morphism that translates fermionic objects into a bosonic form.

In Feynman notation: $e^- + e^+ \to \gamma$

Within the category framework, this transformation adheres to the conservation principles where fermion-antifermion pairs map to bosonic elements.

- $X_{q_{\text{red}}} \cdot Y_{\overline{q}_{\text{green}}} = -C_{g_{\text{red anti-green}}}$:

  In this interaction, a red quark ($X_{q_{\text{red}}}$) interacts with an anti-green quark ($Y_{\overline{q}_{\text{green}}}$) to produce a gluon ($-C_{g_{\text{red anti-green}}}$). The morphism in this context represents a strong interaction where the quarks exchange color charges.

  In Feynman notation: $q_{\text{red}} + \overline{q}_{\text{green}} \to g_{\text{red anti-green}}$

  Algebraically, this transformation captures how quarks interact to exchange color charge, producing gluons.

- $-C_{g_{\text{red anti-green}}} \cdot Y_{q_{\text{green}}} = X_{q_{\text{red}}}$:

  Here, the gluon $-C_{g_{\text{red anti-green}}}$ interacts with a green quark ($Y_{q_{\text{green}}}$), transforming it into a red quark ($X_{q_{\text{red}}}$). This process illustrates how gluons mediate color charge exchanges between quarks, with the morphism translating one color state into another.

  In Feynman notation: $g_{\text{red anti-green}} + q_{\text{green}} \to q_{\text{red}}$

  The category-theoretic approach captures the color transformation through gluon-quark interactions.

- $Y_{q_{\text{green}}} \cdot Z_{\overline{q}_{\text{blue}}} = -A_{g_{\text{green anti-blue}}}$:

  In this interaction, a green quark ($Y_{q_{\text{green}}}$) and an anti-blue quark ($Z_{\overline{q}_{\text{blue}}}$) combine to form a gluon ($-A_{g_{\text{green anti-blue}}}$), demonstrating a strong interaction.

  In Feynman notation: $q_{\text{green}} + \overline{q}_{\text{blue}} \to g_{\text{green anti-blue}}$

  The interaction reflects how quark-antiquark pairs emit gluons with specific color-anticolor charges.

- $-A_{g_{\text{green anti-blue}}} \cdot Z_{q_{\text{blue}}} = Y_{q_{\text{green}}}$:

  This interaction shows the gluon $-A_{g_{\text{green anti-blue}}}$ transforming a blue quark ($Z_{q_{\text{blue}}}$) into a green quark ($Y_{q_{\text{green}}}$), illustrating gluon-mediated color charge transfer.

  In Feynman notation: $g_{\text{green anti-blue}} + q_{\text{blue}} \to q_{\text{green}}$

  The morphism captures the transfer of color charge through gluon-quark interactions in the category of strong force interactions.

3 Color Confinement and QCD-Like Dynamics

In this framework, quarks and gluons arise not as representations of gauge symmetries but as algebraic elements with inherent color properties and interaction rules dictated by the dualistic structure of the theory. Here, X, Y, and Z correspond to quarks with red, green, and blue charges, respectively, while A, B, and C represent gluon-like elements that facilitate color exchanges without directly altering the underlying charge conservation.

3.1 Color Confinement Through Algebraic Constraints

Color confinement in this theory arises from the inherent structure of the parentheses notation, which restricts allowable combinations of X, Y, and Z in any composite state. Specifically, each composite particle state within parentheses must contain no more than one X, one Y, and one Z, ensuring that any bound state remains color-neutral. This isomorphic structure enforces a rule similar to the requirement of color neutrality in Quantum Chromodynamics (QCD) but achieves it through algebraic restrictions rather than gauge symmetries.

- **Single Quark Color States:** The notation forbids isolated quark states. Any attempt to form a particle state with only one of X, Y, or Z would violate the confinement condition and is thus not an allowed physical state.
- **Composite Color-Neutral States:** Bound states, such as baryons, can form when they include one of each color charge (e.g., $X \cdot Y \cdot Z$). This composition satisfies the parentheses notation, ensuring that the resultant state is color-neutral, akin to QCD's color-singlet states.

3.2 Duality Between Quarks and Gluons

In this framework, gluon-like elements A, B, and C enable color exchange interactions by pairing color charges without altering the fundamental color confinement constraints. Each gluon element is associated with specific color-anticolor pairs:

- A: Can carry any color-anticolor pair except for red or anti-red, making it a dual to X.
- B: Can carry any pair except green or anti-green, making it a dual to Y.
- C: Can carry any pair except blue or anti-blue, making it a dual to Z.

These elements obey transformation rules under the group structure, facilitating color exchange between quarks while preserving the total color neutrality of composite states. For instance, a red X quark interacting with an anti-green Y quark through the gluon $-C$ results in a color exchange, yielding a composite state that conserves color charge.

3.3 Interaction Examples: Quark-Gluon Exchange and Color Transformation

The following examples illustrate how the algebraic structure models interactions between quarks and gluons, allowing for color exchanges while maintaining confinement:

- **Example:** $X_{q_{\text{red}}} \cdot Y_{\overline{q}_{\text{green}}} = -C_{g_{\text{red anti-green}}}$

  In this interaction, a red quark $X_{q_{\text{red}}}$ interacts with an anti-green quark $Y_{\overline{q}_{\text{green}}}$, producing a gluon-like element $-C_{g_{\text{red anti-green}}}$. This process reflects the exchange of color charge mediated by gluons, mirroring QCD's color dynamics without requiring gauge fields.

  In Feynman-like notation: $q_{\text{red}} + \overline{q}_{\text{green}} \to g_{\text{red anti-green}}$.

- **Example:** $-C_{g_{\text{red anti-green}}} \cdot Y_{q_{\text{green}}} = X_{q_{\text{red}}}$

  Here, the gluon $-C_{g_{\text{red anti-green}}}$ interacts with a green quark $Y_{q_{\text{green}}}$, transforming it into a red quark $X_{q_{\text{red}}}$. This interaction demonstrates how gluons facilitate the transfer of color charge between quarks, constrained by the algebraic structure of the theory.

  In Feynman-like notation: $g_{\text{red anti-green}} + q_{\text{green}} \to q_{\text{red}}$.

3.4 Quark Self-Interaction and the Emergence of Gluon Exchange Patterns

Self-interaction between quarks can give rise to color-neutral composite states. For instance, in interactions involving multiple color and anti-color states, the gluon-like elements facilitate color exchanges while ensuring that resulting bound states retain net neutrality. Consider:

$$-C_{q_{\text{red anti-green}}} \cdot C_{q_{\text{anti-red green}}} = I_{q_{\text{red anti-red green anti-green}}}$$

This example shows that gluon-gluon interactions between color-anticolor pairs result in color-neutral states. As gluons exchange color between quarks in this framework, they replicate patterns observed in QCD.

3.5 Potential and Charge Structure of Color States

In this model, color and anti-color distinction corresponds to charge polarity. A quark with red charge is associated with positive potential in Hamiltonian terms, while anti-red is associated with negative potential. This alignment provides a physical basis for interpreting the color charge as a potential structure in space-time, governed by specific values of σ and ν (parameters governing the scaling and strength of interactions). For example:

- When color charge is assigned a positive potential, such as X_{red}, it corresponds to a strong force scaling factor that increases with distance.
- Conversely, anti-color (e.g., $X_{\text{anti-red}}$) is represented by a negative potential, scaling similarly but with opposite sign.

Thus, color confinement and charge neutrality in this theory emerge from the algebraic dynamics and scaling behavior rather than a gauge symmetry, resulting in a QCD-like structure through intrinsic properties of the algebra.

Asymptotic Freedom and the Strong Force

In this framework, the scaling behavior of the strong force with energy—known as *asymptotic freedom*—is attributed to an underlying dependence within the parameter λ for states containing the strong force. As energy increases, specific terms within λ dynamically adjust the curvature (or force strength), leading to a reduction in the interaction strength between color-charged particles.

While the exact functional form of this energy dependence in λ remains undetermined, we propose that λ includes terms allowing for an inverse relationship between force strength and energy. This qualitative behavior aligns with the observed phenomenon of asymptotic freedom in Quantum Chromodynamics (QCD), where the force between quarks decreases at higher energy scales.

By embedding this energy sensitivity within λ, the theory naturally captures the behavior of a weakening strong force with increasing energy, consistent with established physical observations.

The Weak Force in the Algebraic Framework

In this theory, the weak force can be understood through the group property:

$$\alpha_1 \cdot \alpha_2 = \alpha_3 \quad \Rightarrow \quad \alpha_3 \cdot \alpha_2 = \alpha_1 \quad \text{and} \quad \alpha_3 \cdot \alpha_1 = \alpha_2$$

This property implies a symmetry in particle interactions that is fundamental to the weak force, particularly in the context of particle-antiparticle annihilation and mediation by weak bosons. Within this algebraic framework, we can interpret these interactions as follows:

Particle Interaction and Weak Bosons

1. **Particle and Anti-Particle Pairing**: Let α_1 represent a particle (e.g., an electron, quark, or neutrino) and α_2 its corresponding anti-particle. The interaction between α_1 and α_2 results in a new entity, α_3, which represents a weak boson ($W^{\pm}$ or Z^0).

2. **Formation of Weak Bosons**: When the particle and anti-particle interact, they form α_3, which can be mathematically expressed as:

$$\alpha_1 \cdot \alpha_2 = \alpha_3$$

Here, α_3 functions as a plane-wave analog for a weak boson that mediates weak interactions. This state, α_3, exists as a result of the interaction between the particle and its anti-particle, and acts as an intermediary in weak force interactions.

Superposition of Weak Boson States

The weak boson α_3 exists in a superposition of particle-antiparticle pairs capable of forming it. For example, a Z^0 boson may exist as a superposition of electron-positron pairs, quark-antiquark pairs, or other lepton-antilepton combinations. We can represent this superposition as:

$$\alpha_3 = \sum_i \alpha_i \cdot \alpha_{\bar{i}}$$

where α_i represents various particles, and $\alpha_{\bar{i}}$ their corresponding anti-particles. Thus, the weak boson α_3 embodies a superposition of these interacting states, reinforcing its role as a mediator capable of facilitating a variety of weak interactions.

Collapse and Weak Force Mediation

Upon interaction, this superposition in α_3 collapses to a specific eigenstate, facilitating a transformation between different particle types. For instance, in charged current interactions, a $W^{\pm}$ boson can mediate a flavor change in quarks or convert a neutrino into a charged lepton.

This process aligns with the group symmetry:

$$\alpha_3 \cdot \alpha_2 = \alpha_1$$

In this expression, α_3 (the weak boson) interacts with α_2 (the anti-particle) to "transform" it back to α_1 (the original particle type). This transformation describes the weak boson's role in mediating particle transformations.

For example, in beta decay: - A down quark (α_1) and a W^- boson (α_3) interact, transforming the down quark into an up quark (α_2). - The W^- boson subsequently decays into an electron and an anti-neutrino, completing the weak interaction.

Within this algebraic framework, the collapse of the weak boson's superposition into a specific eigenstate allows the precise determination of the particles involved in the interaction, facilitating a coherent description of weak force dynamics.

Interpretation of Weak Force Dynamics

- When a particle (α_1) and its anti-particle (α_2) interact, they annihilate to form α_3 (a weak boson). - The weak boson α_3 exists in a superposition of particle-antiparticle states until it interacts and collapses to a specific state, which mediates the transformation. - This interaction dynamically "transforms" one particle type into another as mediated by the weak boson, governed by the algebraic structure and symmetry of the group.

Thus, the weak force is represented as a transformation process between particle types, mediated by weak bosons, with the properties of this interaction encoded in the algebraic symmetries of the group.

The probability of interaction between two particles through the weak force is given by the parentheses notation:

$$P_{\text{interaction}} = (\alpha_1 \cdot \alpha_2 | \alpha_1 \cdot \alpha_2)$$

This expression calculates the probability that the interaction between α_1 and α_2 will result in the formation of α_3, a weak boson that mediates the interaction.

4 Entanglement and Superposition in Atomic and Non-Atomic Systems

This model differentiates between entanglement and superposition as distinct processes, especially in systems involving multiple particles. The primary distinction lies in how α-states combine and how normalization constants are shared (or remain independent) across different particles, affecting the coherence and interactions within and between atoms.

To illustrate, we start with two particles, each having an up and down component in its α-state:

$$\psi_1 = \psi_{\text{up}_1} + \psi_{\text{down}_1}$$
$$\psi_2 = \psi_{\text{up}_2} + \psi_{\text{down}_2}$$

To create entanglement, we combine these components so that they share normalization constants between them, as follows:

$$\left(c_1 \psi_{\text{up}_1} + c_2 \psi_{\text{down}_1}\right) + \left(c_2 \psi_{\text{up}_2} + c_1 \psi_{\text{down}_2}\right)$$

In this representation, the parentheses notation indicates that two distinct α-states, corresponding to separate particles, are combined with shared normalization constants c_1 and c_2. These constants link the particles such that if one is spin-up, the other is spin-down, thus establishing entanglement.

By contrast, superposition without entanglement occurs when each particle's normalization constant remains independent, as shown here:

$$(c_1\psi_1) + (c_3\psi_2)$$

In this case, each particle exists in its own superposition but does not share normalization constants with the other particle. This independent configuration allows for a superposition state across multiple systems without requiring entanglement.

This leads us to differentiate three key processes:

1. Entanglement: Particles share normalization constants and are linked in a quantum α-state, where the measurement of one particle affects the other.
2. Superposition within an atomic system: Particles coexist within a single normalized system represented by parentheses notation, without requiring entanglement.
3. Superposition across atomic systems: Particles in separate systems (atoms) can exist in superposition states with independent normalization constants, indicating coexistence without entanglement.

These distinctions imply that superposition across atoms logically precedes entanglement in complexity, with entanglement being a specialized form of superposition due to its shared normalization constants.

5 Atomic Superposition and Particle Sharing Across Systems

In this model, parentheses notation represents a distinct atomic or composite system, typically formed by combining elementary particles such as G, X, Y, and Z, each representing components of an atom (e.g., leptons or quarks). However, a unique situation arises when one or more of these particles (especially the lepton G) exists in superposition across multiple atoms.

Consider an atomic system represented as $(G + X + Y + Z)$. In cases where the G particle is shared in superposition across multiple atomic systems, this can be represented as follows:

$$G_{\text{total}} = \frac{1}{n}G_1 + \frac{1}{n}G_2 + \cdots + \frac{1}{n}G_n$$

Here, the G particle from one atomic system is shared across n distinct systems (atoms). Despite the superposition's shared normalization constant, each individual G retains a local normalization of 1 within each atom. This arrangement suggests that particles in superposition, without entanglement, may exist across different systems while maintaining a total normalized structure, rather than strictly belonging to a single atom.

In summary, this model differentiates atomic superposition from inter-system superposition:

- Atomic superposition: Particles within an atomic system (e.g., $(G + X + Y + Z)$) coexist in a normalized α-state without entanglement.

- Superposition across atoms: A particle (e.g., G) exists in superposition with others across multiple atoms, with shared normalization constants across systems, yet without entanglement.

This approach offers a framework where particles can maintain coherent α-states across systems without requiring entanglement, expanding the understanding of atomic structure and quantum interactions in non-atomic systems. Notably, this model allows for an arbitrarily large number of particles in superposition states, limited primarily by their shared normalization constants and entanglement interactions.