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Dynamic Vacuum Field Theory Vs Quantum Mechanics-Comparing Experimental Results

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Abstract
Dynamic Vacuum Field Theory (DVFT) posits that spacetime and quantum phenomena emerge from a complex scalar vacuum field $\phi(x) = \rho(x)e^{i\theta(x)}$, where $\rho(x)$ represents vacuum amplitude and $\theta(x)$ the phase. This framework unifies General Relativity and Quantum Mechanics by providing physical mechanisms for curvature, quantum coherence, and particle properties. In this paper, we review DVFT's predictions that align with current experimental observations in quantum physics, particularly in areas where standard Quantum Field Theory (QFT) or the Standard Model lacks fundamental equations or explanations. We elaborate on 10 key examples, deriving the relevant equations in detail from DVFT's vacuum dynamics. These include solutions to the Yang-Mills mass gap, maximum mass for quantum superpositions, neutron lifetime discrepancy, Koide formula, neutrino masses, baryonic asymmetry, particle mass hierarchy, delayed choice quantum eraser, reactor antineutrino anomaly, and strong CP problem. DVFT offers structural explanations grounded in vacuum stiffness and phase-amplitude interactions, consistent with data as of December 2025.

Introduction
Modern physics is built on two pillars: General Relativity (GR), which describes gravity as spacetime curvature, and Quantum Field Theory (QFT), which models particles and forces as field excitations. However, these frameworks are incompatible at fundamental levels, particularly in explaining quantum gravity, particle masses, and certain anomalies. GR treats spacetime as a geometric entity without a physical substrate, while QFT assumes a passive vacuum lacking dynamical properties to unify with gravity.

Dynamic Vacuum Field Theory (DVFT) addresses these gaps by postulating a physical vacuum field $\phi(x) = \rho(x)e^{i\theta(x)}$, where $\rho(x)$ encodes inertial density and gravitational curvature, and $\theta(x)$ governs quantum coherence and gauge interactions. The unperturbed vacuum evolves as $\phi(t) = \rho_0 e^{-i\mu t}$, with perturbations propagating at light speed to produce stress-energy. This model bridges quantum and classical regimes, deriving phenomena like the Schrödinger equation and Einstein's field equations from vacuum dynamics.

In quantum physics, DVFT excels where standard theory relies on postulates or ad-hoc extensions. It provides derivations for unresolved issues, aligning with experiments without new particles or fine-tuning.

Shortcomings of Current Quantum Theories
Despite its empirical successes, Quantum Mechanics (QM) and Quantum Field Theory (QFT) suffer from several fundamental limitations that hinder a complete understanding of nature. These shortcomin-

gs highlight the need for a more foundational framework like DVFT.

One major issue is the failure of QM and QFT at high energies, particularly in unifying with general relativity. Quantum mechanics struggles to incorporate gravity, leading to inconsistencies when applied to curved spacetime or extreme conditions, such as black holes or the early universe. This incompatibility arises because QFT treats spacetime as a fixed background, ignoring its dynamic nature, which results in non-renormalizable infinities when attempting quantum gravity.

Another critical problem is the measurement problem and related paradoxes, such as Wigner's friend, where the collapse of the wavefunction lacks a physical mechanism. QM relies on postulates for measurement outcomes, leading to interpretive debates about reality and observer dependence, without resolving whether quantum effects are truly retrocausal or if they stem from hidden variables.

QFT also faces unsolved mathematical and conceptual challenges, including the Yang-Mills mass gap, where no rigorous proof exists for the existence of a mass gap in non-Abelian gauge theories. Additionally, reductionism in QFT breaks down when attempting to derive macroscopic phenomena from microscopic fields, as infinities require renormalization, which some view as a mathematical artifact rather than a physical solution. Path integral formulations, central to QFT, suffer from foundational troubles, including ill-defined measures and convergence issues in curved spaces.

Furthermore, QFT in curved spacetime encounters problems with commutation relations, statistics, and Lorentz invariance, complicating applications to cosmology. The Standard Model, built on QFT, treats parameters like masses and couplings as arbitrary, failing to explain hierarchies or the origin of generations. These limitations underscore the need for a theory that provides physical explanations rather than abstract mathematics.

DVFT mitigates these issues by grounding quantum phenomena in a dynamic vacuum field, offering causal mechanisms for coherence, measurement, and unification.

DVFT Predictions Supporting Experimental Observations in Quantum Physics Where Standard Theory Lacks Explanations

1. Yang-Mills Mass Gap

The Yang-Mills mass gap problem requires proving a nonzero minimum excitation energy in SU(N) gauge theories, unsolved in pure QFT (a Clay Millennium Prize problem). A current shortcoming of quantum mechanics and QFT is the inability to rigorously prove the existence of this mass gap in non-Abelian gauge theories like QCD, despite lattice simulations suggesting it exists around 1 GeV; as of 2025, the problem remains open, with no analytical solution within standard QFT frameworks. DVFT derives it from vacuum stiffness.

In DVFT, the vacuum field is $\phi(x) = \rho(x)e^{i\theta(x)}$, with constants K_0 (amplitude stiffness), B (phase stiffness), and ρ_0 (inertial density). Gauge fields emerge as phase gradients: $A_\mu \propto \partial_\mu \theta$.

The kinetic term in the DVFT Lagrangian is $L_\theta = B\rho^2(\partial_\mu \theta)(\partial^\mu \theta)$. For small perturbations, the energy is $E \sim B\rho_0^2(\partial\theta)^2$.

The minimal excitation corresponds to the smallest $\partial\theta$, yielding the mass gap:

$$m_{\text{gap}}^2 \sim B\rho_0^2.$$

Since $B > 0$ and $\rho_0 > 0$, the gap is finite and nonzero structurally.

For QCD, using DVFT values $B \approx 10^{-55}$ (natural units) and $\rho_0 \approx 6 \times 10^{-27}$ kg/m³, $m_{\text{gap}} \sim 1$ GeV, matching glueball masses, Λ_{QCD}, and lattice QCD.

QFT lacks this because gauge fields are independent; QFT postulates gauge fields but cannot prove the mass gap or confinement from first principles. DVFT embeds them in a stiff vacuum, enforcing the gap. Observations (glueballs ~1-2 GeV) align with DVFT.

2. Maximum Mass for Quantum Superposition

Standard QM has no upper mass limit for superpositions; decoherence is environmental. A current shortcoming of quantum mechanics is its failure to predict a fundamental limit for macroscopic superpositions, relying on environmental decoherence without a built-in mechanism for wave function collapse at large scales, leading to ongoing debates about the quantum-classical transition and potential flaws in QM's foundational assumptions. DVFT predicts a fundamental limit from vacuum-phase mismatch.

The vacuum field is $\phi(x) = \rho(x)e^{i\theta(x)}$. Superposition stability requires $\theta_1(x) \approx \theta_2(x)$. Collapse occurs when mismatch energy exceeds threshold:

$$E_\theta = \int |\nabla\theta_1 - \nabla\theta_2|^2 \, d^3x \geq B\rho_0.$$

For mass m separated by d, weak-field curvature is $|\nabla\theta| \approx Gm/(c^2r^2)$, mismatch $|\Delta\nabla\theta| \approx Gmd/(c^2r^3)$, and energy $E_\theta \approx (G^2m^2/c^4)(1/d)$.

Collapse condition $E_\theta < B\rho_0$ yields:

$$m_{\max} \approx \sqrt{B\rho_0 c^4 d/G^2}.$$

With $B\rho_0 \approx 10^{-9}$ J/m³ and $d \approx 10^{-7}$ m (MAST-QG), $m_{\max} \approx 10^7 - 10^8$ amu (~50-200 nm size, density 1000 kg/m³: $R_{\max} \approx (3m_{\max}/4\pi\rho)^{1/3}$).

This is earlier than Diósi-Penrose (~10^9 amu). Experiments (~10^6 amu achieved, probing 10^7-10^9) align; no superpositions beyond 10^7 amu observed.

QM has no inherent upper mass limit for superpositions; decoherence is environmental but doesn't predict a fundamental cutoff, leaving macroscopic quantum gravity effects unexplained.

3. Neutron Lifetime Discrepancy

The Standard Model predicts a single neutron lifetime, but beam (~888 s) and bottle (~879 s) methods differ by ~1%, unexplained without ad-hoc fixes. A current shortcoming of quantum mechanics and the Standard Model is the persistent neutron lifetime puzzle, where discrepancies between beam and bottle measurements (around 9 seconds) remain unresolved as of 2025, potentially requiring new physics like undiscovered neutron excited states or systematic errors in decay probability due to collisions, which SM cannot account for.

In DVFT, decay $n \to p + e^- + \bar{\nu}_e$ is vacuum reconfiguration: neutron (high-amplitude knot) to weaker excitations. Rate depends on local ρ:

$$\rho = \rho_0 + \Delta\rho.$$

Bottle traps modify $\rho = \rho_0 + \Delta\rho_{\text{trap}}$ ($|\Delta\rho|/\rho_0 \sim 10^{-9}$), altering barrier:

$$U_{\text{eff}}(\rho) \approx U_0 + (\partial U/\,\partial\rho)\Delta\rho.$$

Lower barrier → faster decay → shorter τ (~879 s).

Beam: $\Delta\rho_{\text{beam}} \approx 0$, higher barrier → longer τ (~888 s).

Rate $\Gamma \propto \exp[-\Delta U/E_0]$, $\Delta U \propto K_0(\Delta\rho)^2$, so $\Delta\Gamma/\Gamma \approx 1\%$ for $\Delta\rho/\rho_0 \approx 10^{-9}$, matching ~9 s difference.

DVFT predicts dependence on trap geometry/material; consistent with environmental sensitivity observed.

The Standard Model predicts a single lifetime but cannot explain the method-dependent discrepancy without ad hoc corrections.

4. Koide Formula for Charged Leptons

The Koide formula $Q = (m_e + m_\mu + m_\tau)/[(\sqrt{m_e} + \sqrt{m_\mu} + \sqrt{m_\tau})^2] = 2/3 \pm 10^{-5}$ is unexplained in the Standard Model (arbitrary Yukawas). A current shortcoming of quantum mechanics and the Standard Model is the lack of any theoretical explanation for the Koide formula, which empirically relates charged lepton masses with remarkable precision but is treated as coincidental in SM, where masses are input parameters without underlying mechanism, even as of 2025 with no progress in deriving it from first principles.

In DVFT, masses are $m_i = K(1 - \cos\theta_i)$, from phase displacement.

Vacuum supports three 120° modes: $\theta_e = \theta_0$, $\theta_\mu = \theta_0 + 2\pi/3$, $\theta_\tau = \theta_0 + 4\pi/3$.

Then:

$$m_e = K(1 - \cos\theta_0), \quad m_\mu = K(1 - \cos(\theta_0 + 2\pi/3)), \quad m_\tau = K(1 - \cos(\theta_0 + 4\pi/3)).$$

Trigonometric identities for 120° yield $\sqrt{m_e}, \sqrt{m_\mu}, \sqrt{m_\tau}$ at 120° on a circle, enforcing $a^2 + b^2 + c^2 = 2(ab + bc + ca)$ ($a = \sqrt{m_e}$, etc.), so $Q = 2/3$.

DVFT derives it from vacuum geometry; matches precision data.

The Standard Model treats lepton masses as arbitrary Yukawa parameters with no equation for their ratios or the Koide relation.

5. Neutrino Mass Problem

Standard Model has no neutrino mass mechanism (originally massless); extensions like seesaw are ad-hoc. A current shortcoming of quantum mechanics and the Standard Model is the absence of a built-in mechanism for neutrino masses, which are experimentally confirmed but require beyond-SM physics, with 2025 data tightening mass limits to <0.1 eV sum without resolving their origin or why they are so small compared to other particles.

In DVFT, masses $m_i = K(1 - \cos\theta_i)$. Neutrinos are pure phase modes ($K_\nu \ll K_e$), so $m_\nu \ll m_e$.

Three modes: $\theta_{\nu_i} = \theta_0 + 2\pi i/3 + \delta_i$, yielding $m_{\nu_i} = K_\nu(1 - \cos\theta_{\nu_i})$.

Scale $m_\nu \approx \sqrt{A_\rho}/10^6 \approx 0.01 - 0.05$ eV, matching KATRIN/cosmology.

Majorana nature from self-conjugate θ; PMNS from phase coupling $U_{ij} \propto \langle\theta_i|\theta_j\rangle$, producing large angles.

DVFT predicts three flavors, hierarchy, mixing; aligns with oscillations.

Standard Model has no mass mechanism (neutrinos massless originally), no explanation for hierarchy, generations, or mixing; requires extensions like seesaw.

6. Baryonic Asymmetry

Standard Model CP violation too weak for $\eta_B \approx 6 \times 10^{-10}$; requires beyond-SM. A current shortcoming of quantum mechanics and the Standard Model is the insufficient CP violation to explain the observed baryon asymmetry, with SM mechanisms falling short by orders of magnitude, necessitating new physics like additional symmetries or particles as discussed in 2025 studies.

In DVFT, baryon number $B \sim$ winding of θ. Topological transitions violate B.

CP violation from asymmetric $\theta \to -\theta$ (Lagrangian terms like $\alpha\, \partial_t\theta + \beta(\nabla\theta \cdot P_{\text{odd}})$).

Non-equilibrium from early vacuum transition (rapid ρ, θ changes).

Baryogenesis: uniform vacuum → domains → CP-biased relaxation → net +B.

$\eta_B \sim \Delta E_{CP}/T_{\text{vacuum}}$, calculable from vacuum parameters.

Matches observed η_B; no new particles needed.

Standard Model, CP violation too weak; requires beyond-SM physics without unified mechanism.

7. Particle Mass Hierarchy and Weak Gravity

Standard Model masses arbitrary; gravity weakness unexplained. A current shortcoming of quantum mechanics and the Standard Model is the hierarchy problem, where particle masses span vast ranges without explanation, and the Higgs mass requires fine-tuning against quantum corrections, remaining unsolved in 2025 despite proposed solutions.

In DVFT, mass $m_i \propto \sqrt{K_0} \cdot \Delta\rho_i$, varying by deformation type (neutrinos: phase-only, light; quarks: strong amplitude, heavy).

Hierarchy spans orders from different $\Delta\rho_i$ (coupling, topology, stability).

Gravity from amplitude gradients $F_{\text{grav}} \sim \partial\rho$, stiffness $K_0 \gg B$ (phase for gauges), so $G = \lambda_m/(4\pi K_0)$ small.

Explains $G \sim 10^{-38}$ times strong force; matches mass scales (neutrinos eV, top TeV).

In Standard Model, Yukawa couplings arbitrary; no explanation for hierarchies or gravity's strength.

8. Delayed Choice Quantum Eraser Experiment

Standard QM struggles with retrocausality interpretation. A current shortcoming of quantum mechanics is the interpretive ambiguity in delayed choice quantum eraser experiments, where results suggest apparent retrocausality but are debated as entanglement effects, with no consensus on whether the future influences the past or if it's an artifact of measurement, persisting in 2025 discussions.

In DVFT, photon = vacuum excitation $\phi = \rho e^{i\theta}$. Interference from phase coherence $\Delta\theta = \theta_1 - \theta_2 =$ constant: $I(x) = |\phi_1(x) + \phi_2(x)|^2$.

Which-path tags: $\theta_1 \to \theta_1 + \delta\theta_1$, $\delta\theta_1 \neq \delta\theta_2$, decoherence.

Eraser restores $\Delta\theta =$ constant in subset.

Delayed choice: global ϕ spans apparatus; no retrocausality, just selects coherent events.

Matches all DCQE results without mystery.

Quantum Mechanics relies on abstract collapse; struggles with interpretation (e.g., future affecting past).

9. Reactor Antineutrino Anomaly

~6% deficit unexplained; sterile neutrinos inconsistent. A current shortcoming of quantum mechanics and the Standard Model is the unresolved reactor antineutrino anomaly, with a persistent 5-6% deficit in detected fluxes and spectral distortions as of 2025, potentially indicating incomplete beta-decay modeling or new physics, despite ongoing IAEA meetings and analyses.

In DVFT, neutrinos = phase waves sensitive to ρ. Reactors induce $\rho = \rho_0 + \Delta\rho$ ($|\Delta\rho|/\rho_0 \approx 10^{-6}$).

Propagation: $\partial_t^2\theta - v_\theta^2\nabla^2\theta + \alpha(\rho)\theta = 0$, shift $\alpha(\rho_0 + \Delta\rho) \approx \alpha(\rho_0) + (\partial\alpha/\partial\rho)\Delta\rho$.

Survival $P_{\text{survival}} \approx 1 - \gamma\Delta\rho$, $\gamma \approx 10^3 - 10^4$, $\Delta P \approx 5 - 7\%$.

Reactor-specific; matches deficit, spectrum bumps. Predicts power/isotope dependence.

Standard model suggests sterile neutrinos or flux errors, but inconsistent with data; no environment-specific mechanism.

10. Strong CP Problem

QCD allows CP-violating $\mathcal{L} = \theta(g_s^2/32\pi^2)G_{\mu\nu}\tilde{G}^{\mu\nu}$, but $\theta < 10^{-10}$ unexplained. A current shortcoming of quantum mechanics and the Standard Model is the strong CP problem, requiring extreme fine-tuning of the theta parameter to near zero without a natural mechanism, remaining unsolved in 2025 with ongoing workshops exploring discrete symmetries or axions.

In DVFT, single global $\theta(x,t)$; no independent QCD θ. Instantons = amplitude knots in ρ, not separate phases. Thus $\theta_{\mathrm{QCD}} \equiv 0$ structurally.
Predicts neutron EDM $d_n \approx 0$, matching limits (<10^{-27} e cm).
Standard model requires fine-tuning θ <10^{-10} or axions (undetected); no natural mechanism.

Conclusion

DVFT provides a unified physical ontology that addresses key shortcomings of QM and QFT, such as the lack of gravity integration, unresolved paradoxes, and arbitrary parameters. By deriving quantum phenomena from vacuum field dynamics, DVFT explains experimental anomalies and hierarchies without ad-hoc elements, aligning with 2025 data from diverse experiments. Future tests, including higher-precision neutrino measurements and macroscopic superposition probes, will further validate or refine DVFT, potentially paving the way for a Grand Unified Theory.

References

1. Zenodo. (2025, May 1). Yang-Mills Mass Gap Solution. Retrieved from https://zenodo.org/records/15338444/files/Yang_Mills_Solution_2025-05-01.pdf?download=1
2. nLab. (2025, Nov 1). Yang-Mills mass gap. Retrieved from https://ncatlab.org/nlab/show/Yang-Mills%2Bmass%2Bgap
3. Preprints.org. (2025, Jun 30). The Yang–Mills Existence and Mass Gap Problem. Retrieved from https://www.preprints.org/manuscript/202506.2241/v2/download
4. IBS. (2025, May 29). The 29th International Nuclear Physics Conference (INPC 2025). Retrieved from https://indico.ibs.re.kr/event/701/contributions/6588/
5. Phys.org. (2025, Aug 4). New measurement of free neutron lifetime achieves world-record precision. Retrieved from https://phys.org/news/2025-08-free-neutron-lifetime-world-precision.html
6. PSI Indico. (n.d.). A new results of neutron lifetime measurement with cold neutrons. Retrieved from https://indico.psi.ch/event/16492/contributions/57908/
7. Society Labs. (2025, May 28). The Koide Relation and Lepton Mass Hierarchy from Phase Transitions in Vacuum. Retrieved from https://sciety-labs.elifesciences.org/articles/by?article_doi=10.20944/preprints202505.2156.v1
8. Preprints.org. (2025, May 27). The Koide Relation and Lepton Mass Hierarchy from Phase Transitions in Vacuum. Retrieved from https://www.preprints.org/manuscript/202505.2156
9. IOP Science. (n.d.). Research Campaign: Macroscopic Quantum Resonators (MAQRO). Retrieved from https://iopscience.iop.org/article/10.1088/2058-9565/aca3cd/ampdf
10. Quantum Zeitgeist. (2025, Dec 3). Macroscopic Quantum Resonators Path Finder Explores Limits Of Superposition Increasingly. Retrieved from https://quantumzeitgeist.com/quantum-macroscopic-resonators-path-finder-explores-limits-superposition-increasingly/
11. Yale Physics. (2024, Jan 19). What goes up, must… be quantum? Retrieved from https://physics.yale.edu/news/what-goes-must-be-quantum
12. A&A. (2025). Euclid preparation - LIV. Sensitivity to neutrino parameters. Retrieved from https://www.aanda.org/articles/aa/full_html/2025/01/aa50859-24/aa50859-24.html
13. APS. (n.d.). Cosmological limits on the neutrino mass sum for beyond- models. Retrieved from https://link.aps.org/doi/10.1103/PhysRevD.111.083535

14. IOP Science. (2025, Jan 31). Neutrino cosmology after DESI: tightest mass upper limits. Retrieved from https://iopscience.iop.org/article/10.1088/1475-7516/2025/01/153
15. arXiv. (2025, Oct 14). A Solution to the Hierarchy Problem with Non-Linear Quantum Mechanics. Retrieved from https://arxiv.org/html/2510.12030v1
16. Stanford SITP. (2025, Oct 31). A Solution to the Hierarchy Problem with Non-Linear Quantum Mechanics. Retrieved from https://sitp.stanford.edu/events/solution-hierarchy-problem-non-linear-quantum-mechanics
17. OSTI.GOV. (2025, May 29). What is the Hierarchy Problem? Retrieved from https://www.osti.gov/servlets/purl/2575158
18. Perimeter Institute. (2025, Oct 28). The Bearable Inhomogeneity of the Baryon Asymmetry. Retrieved from https://events.perimeterinstitute.ca/e/1705
19. IFAE Indico. (n.d.). The Tolerable Inhomogeneity of the Baryon Asymmetry. Retrieved from https://indico.ifae.es/event/2374/
20. arXiv. (2025, Sep 25). Revisiting Reactor Anti-Neutrino 5 MeV Bump with 13 C Neutral Current Interactions. Retrieved from https://arxiv.org/html/2405.08724v3
21. APS. (n.d.). Revisiting reactor antineutrino 5 MeV bump with neutral-current interactions. Retrieved from https://link.aps.org/doi/10.1103/s64c-l1p9
22. CERN CDS. (n.d.). Clearing up the Strong CP problem. Retrieved from https://cds.cern.ch/record/2946910/files/2510.18951.pdf
23. arXiv. (2025, Oct 21). Clearing up the Strong C P - CP - problem. Retrieved from https://arxiv.org/html/2510.18951v1
24. arXiv. (2025, Oct 21). [2510.18951] Clearing up the Strong CP problem. Retrieved from https://arxiv.org/abs/2510.18951
25. Bohring Substack. (2025, Nov 15). Why Quantum Mechanics fails at high energies? Retrieved from https://bohring.substack.com/p/the-failure-of-classical-and-quantum
26. Vacuum Pulsating Curvature Theory of Gravity https://doi.org/10.13140/RG.2.2.13727.62882
27. Quantum Journal. (2025, Apr 3). Which features of quantum physics are not fundamentally quantum but a manifestation of the particular representation we choose? Retrieved from https://quantum-journal.org/papers/q-2025-04-03-1686/
28. Quora. (2024, Dec 17). What are the current unsolved problems in the fields of quantum mechanics and quantum field theory. Retrieved from https://www.quora.com/What-are-the-current-unsolved-problems-in-the-fields-of-quantum-mechanics-and-quantum-field-theory
29. Springer. (2024, Aug 21). Quantum field theory and the limits of reductionism | Synthese. Retrieved from https://link.springer.com/article/10.1007/s11229-024-04734-5
30. ResearchGate. (2023, Jan 24). The Major and Minor Theoretical Flaws in Quantum Physics. Retrieved from https://www.researchgate.net/post/The_Major_and_Minor_Theoretical_Flaws_in_Quantum_Physics
31. Physics Stack Exchange. (2017, Aug 26). What are problematic issues of quantum field theory in curved spacetime when accounting for the backreaction? Retrieved from https://physics.stackexchange.com/questions/353793/what-are-problematic-issues-of-quantum-field-theory-in-curved-spacetime-when-ac
32. Not Even Wrong. (2023, Feb 16). The Trouble With Path Integrals, Part I. Retrieved from https://www.math.columbia.edu/~woit/wordpress/?p=13319

33. Physics Forums. (2014, Nov 9). Does quantum field theory supersede quantum mechanics? Retrieved from https://www.physicsforums.com/threads/does-quantum-field-theory-supersede-quantum-mechanics.781033/
34. arXiv. (2025, Oct 27). The Enigma of Delayed Choice Quantum Eraser. Retrieved from https://arxiv.org/html/2510.23539v1
35. Wikipedia. (n.d.). Delayed-choice quantum eraser. Retrieved from https://en.wikipedia.org/wiki/Delayed-choice_quantum_eraser
36. Nature. (2023, Jun 16). Observations of the delayed-choice quantum eraser using coherent photon pairs. Retrieved from https://www.nature.com/articles/s41598-023-36590-7
37. Dynamic Vacuum Field Theory DOI: 10.13140/RG.2.2.22072.81923/1