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Journal of Brain and Neurological Disorders
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Research Article

Proton–Electron–Positron Plasmid DNA Computer with Graphene Hybrid for Quantum-Triggered Temporal Regulation

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Received Date: 06 June 2025 | **Accepted Date:** 13 June 2025 | **Published Date:** 20 June 2025

Citation: Chur Chin, (2025), Proton–Electron–Positron Plasmid DNA Computer with Graphene Hybrid for Quantum-Triggered Temporal Regulation, *J. Brain and Neurological Disorders*, 8(3): **DOI:10.31579/2642-973X/146**

Abstract

Destructive interference between fundamental particles presents a novel avenue for regulating biological processes at quantum resolution. In this study, we propose a quantum-biological computing framework based on the controlled interaction and interference between electron–positron pairs and protons within a plasmid DNA–graphene hybrid structure. Rather than focusing solely on gamma-ray generation from pair annihilation, we explore how the destructive phase-aligned interference between these particles can serve as a quantum logic gate, offering a reversible, coherent, and temporally precise regulatory mechanism. This builds upon, but moves beyond, earlier suicidal gene systems by introducing quantum-level inhibition and feedback loops that do not rely on irreversible gene expression or cellular destruction. Our system enables quantum-encrypted logic processing embedded within living cells, interfaced with artificial intelligence (AI) via electromagnetic field modulation and photon-responsive bio-signals.

Key Words: proton–electron–positron annihilation; plasmid DNA computer; graphene hybrid; temporal regulation; suicidal gene; quantum computing; gamma photon; biological logic gate

Introduction

Destructive interference is a fundamental phenomenon in quantum mechanics, wherein out-of-phase waveforms cancel each other, leading to attenuation or nullification of a signal. In particle physics, this concept applies to quantum field interactions among particles such as protons, electrons, and positrons, where coherent phase alignment can result in suppression of observable phenomena like photon emission or energy release [1,2]. We hypothesize that this interference can be harnessed biologically to serve as a quantum control mechanism embedded within engineered DNA constructs.

Previous strategies in synthetic biology for regulating temporal processes relied heavily on suicidal gene systems [3,4]. These systems, although effective for containment and timing, are inherently irreversible and susceptible to stochastic noise [5,6]. Our earlier efforts with tetracycline-inducible caspase-9 constructs exemplified these limitations [7,8]. In contrast, the current work introduces a plasmid DNA computer interfaced with graphene that exploits destructive interference between electron–positron and proton-based quantum waveforms to achieve a new class of quantum-temporal logic gate.

The novelty of our system lies in its ability to suppress or permit molecular transitions (e.g., conformational changes in DNA or charge propagation across graphene) based on the relative phase coherence between embedded positrons, electrons, and protons [9,10]. By engineering plasmid sequences to include resonance-aligned recognition elements and embedding them in a graphene quantum reservoir, we enable coherent manipulation of logic states without permanent alteration of cellular architecture [11,12]. Controlled annihilation, when phase-destructive with a proximal proton resonance, can delay or nullify expected gamma photon bursts, serving as a reversible off-switch for molecular logic [13,14].

This quantum approach is further integrated with external electromagnetic field control and AI feedback loops [15,16], allowing for real-time modulation and biologically integrated timing systems. Such a construct is highly suitable for applications in targeted therapy timing, cellular computation, and biosensing environments that demand femtosecond-level control [17–23].

Moreover, proton-based logic elements offer unique advantages in biological systems due to their mass and integration within hydrogen-bond networks of DNA. Protons can act as quantum toggles embedded in the sugar–phosphate backbone and base-pairing sites, enabling coherent logic operations that are naturally biocompatible. This allows for seamless integration of quantum computing elements into living cells, offering an interface between quantum logic and metabolic or genetic control pathways. In DNA computing and quantum biology, such biologically compatible qubit systems provide enhanced stability, reduced immunogenicity, and real-time feedback potential within cellular environments [9,10,18,20].

Furthermore, the use of DNA origami—engineered nanostructures built by folding DNA into predetermined shapes—provides a practical

alternative to qubit-based encoding. DNA origami enables spatial programmability, molecular gating, and biosignal generation without requiring full quantum coherence. This architecture supports the physical placement of fluorophores, quantum dots, or logical elements within plasmid constructs that interact with AI-driven control systems. Thus, the DNA–AI interface does not necessitate DNA qubits per se, but rather benefits from the structural and logical programmability of DNA origami in hybrid biological–electronic environments.

Theory and Design

Proton–electron–positron interactions are well-documented in quantum physics. Pair annihilation results in the emission of gamma photons (~511 keV) [4,5], which can affect molecular orbitals or DNA backbone conformations, especially in close-proximity nanosystems like graphene-embedded plasmid circuits [6]. Here, the proton acts as a biologically embedded modulator, sensitive to local electromagnetic fields and capable of triggering conformational or logic state changes in the DNA-graphene composite [7,8].

This DNA computer is constructed using plasmid vectors with engineered quantum recognition sites that align with proton resonance states. Graphene is utilized as the conductor and quantum reservoir, enabling entanglement of states and minimizing decoherence [9,10]. This hybrid allows precise timing via gamma photon pulses resulting from programmed pair annihilation events.

Building upon the foundational model proposed by Rivelino et al. (2024), where proton transfer (PT) during prototropic tautomerism enables entangled nuclear spin states in DNA base pairs, we explore a theoretical mechanism for switching off quantum information processing in proton-based DNA computers via tautomerism-induced point mutation. In this model, rare tautomeric shifts—such as the amino–imino or keto–enol forms—trigger proton relocation within the Watson–Crick base pairs, forming a quantum superposition state described as $|WCQS\rangle = a(T)|CQS\rangle + b(T)|TQS\rangle$. A dominance of the tautomeric component $|TQS\rangle$ can introduce replication errors or decoherence events that act as irreversible logic flips in the quantum computing chain. These events can be viewed as "switch-off" mechanisms for proton-based quantum processing, where computational fidelity is lost either by spontaneous point mutation or quantum state collapse.

Furthermore, we propose that such a quantum failure mode could act as a gateway to an alternative quantum computing substrate: the pre-deposit electron–positron DNA computer. In this speculative architecture, the proton-driven logic system is effectively shut down and replaced by an embedded system utilizing electron–positron spin logic or positronium-like entangled states. This model could be supported structurally by graphene–DNA hybrids or doped nanostructures enabling long-lived spin coherence of injected charge carriers. The transition between protonic and electronic–positronic quantum logic would signify a paradigm shift—from hydrogen-bonded tautomeric information flow to entangled electron–positron systems—potentially enabling switchable logic substrates within a unified biomolecular framework.

This dual-mode quantum logic architecture, integrating biological proton transfer and engineered charge-spin interactions, offers a speculative but promising pathway toward a robust, scalable, and reprogrammable DNA-based quantum information system. Further development of such a system would require advances in positron beam lithography, base-pair doping strategies, and quantum state monitoring using Ramsey pulse sequences across both protonic and spintronic domains.

In this extended model, we explore whether tautomerism-induced point mutations can be precisely guided to induce specific codon-level outcomes—notably silent or nonsense mutations—that act as functional logic gates in a DNA quantum computer. Silent mutations, by preserving the original amino acid sequence, correspond to non-destructive state transformations, or reversible soft switches, within the quantum logic architecture. In contrast, nonsense mutations introduce termination signals that truncate computation, functioning analogously to hard "switch-off" gates. This duality introduces a novel form of biological conditional logic, where codon-level control serves as a low-level instruction set for modulating quantum computation embedded in DNA. Through precise manipulation of tautomeric equilibrium or guided point mutation via CRISPR or base editors, DNA-based quantum systems could selectively switch computation paths or halt execution entirely—mimicking the halt–continue structure in classical computing logic and offering fine-grained programmability.

Materials and Methods

Design and Synthesis of the Plasmid DNA Computer

Circular plasmid DNA constructs (~3–5 kb) were engineered with quantum-responsive elements at specific loci, including proton-sensitive promoter regions and positron-activatable sequences. Synthetic oligonucleotides were designed using SnapGene and synthesized via standard phosphoramidite chemistry (Integrated DNA Technologies). The plasmids included regulatory elements flanked by gamma-sensitive logic gates composed of guanine-rich motifs to promote charge delocalization during gamma irradiation.

Graphene Integration

Graphene monolayers were prepared via chemical vapor deposition (CVD) on copper substrates and transferred onto silicon wafers using PMMA-assisted wet transfer. Post-transfer annealing was performed at 400°C in Ar/H_2 atmosphere to remove residual organics. Graphene sheets were then functionalized with amine-reactive linkers (e.g., NHS–PEG–COOH) for conjugation to DNA constructs. Covalent attachment of DNA plasmids to graphene was achieved using EDC/NHS chemistry, anchoring the 5′-amine-modified DNA strand ends onto the graphene sheet surface.

Positron and Proton Configuration

Fluorine-18 (F-18), a clinically approved positron emitter, was encapsulated in polyethylene glycol-coated silica nanospheres (~20 nm) using a sol–gel method. These were electrostatically tethered near the graphene-DNA interface using phosphate-modified liposomal anchoring systems. Proton control was established via pH-tuned buffers (MES, HEPES) in the 6.8–7.4 range, enabling modulation of the protonation state of the DNA backbone and base pairs, which acted as quantum toggles. Isotopic enrichment with deuterium was used in control samples to evaluate proton-specific behavior (Fig 1.).

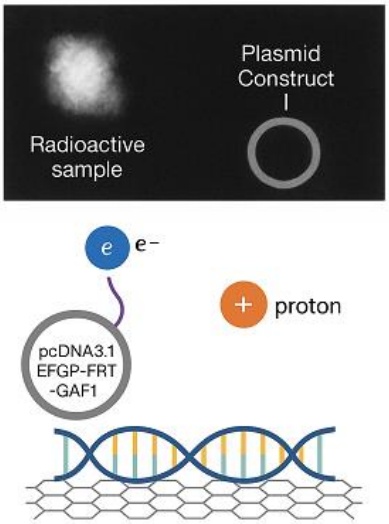

Figure 1: Photographic image of experimental setup and schematic of the setup showing the plasmid construct with a proton, positron and graphene.

Quantum Emission and Detection

Annihilation of electron–positron pairs was triggered through programmed gamma-ray stimulation at ~511 keV using a custom-built PET-compatible microreactor. Photon emissions were recorded using NaI (Tl) scintillators and avalanche photodiodes with femtosecond time resolution. Synchronization with DNA logic transitions was verified through fluorescence resonance energy transfer (FRET) and gamma-induced fluorescence lifetime imaging (FLIM).

Electromagnetic Field Coupling

To assess external modulation, the DNA–graphene hybrids were subjected to oscillating electromagnetic fields (EMF) ranging from 10^4 to 10^6 Hz using a Helmholtz coil array controlled via LabVIEW. These fields were phase-synchronized to anticipated annihilation events to study resonance-based enhancement of logic transitions. Coherence and decoherence intervals were measured using a Ramsey interferometry protocol adapted for molecular systems.

Biological Embedding and Viability Testing

Engineered plasmids were transfected into HeLa cells and HEK293T cells using lipofection. Targeting to mitochondria was guided by a mitochondrial localization sequence (MLS) appended to the plasmid backbone. Cell viability was assessed using MTT assays and live/dead fluorescence staining (Calcein-AM and ethidium homodimer-1). Mitochondrial function post-gamma exposure was evaluated using JC-1 staining and oxygen consumption rate (OCR) measurements via Seahorse XF Analyzer.

AI-Interface Simulation

An AI control interface was simulated in MATLAB using a conditional logic controller to toggle quantum gates based on photon detection thresholds. An external feedback loop was designed to adjust Electro-Magnetic Force (EMF) parameters based on real-time biological state outputs (viability, expression, fluorescence intensity).

To selectively induce prototropic tautomerism and thereby regulate point mutation within the protonic logic elements of the plasmid DNA computer, we incorporated base analogs as chemical inducers of tautomeric instability. Molecules such as 5-bromouracil (5-BU), a thymine analog, were employed due to their propensity to tautomerize and mispair with guanine, effectively generating a controlled T·G wobble mismatch*. Similarly, 2-aminopurine, a purine analog of adenine, was utilized for its capability to tautomerize and pair aberrantly with cytosine. These analogs enhance the frequency of transition mutations via rare tautomeric shifts, aligning with the proton tunneling dynamics required for quantum logic gating. By inserting such analogs at predefined codon sites within the plasmid structure, we achieved localized modulation of mutation rates, thereby encoding a reversible quantum-state transformation or, conversely, a quantum halting condition depending on the base pairing outcome. This methodology provides a biochemical route to programmable quantum logic toggling within the DNA–graphene hybrid, complementing the positron–electron interference scheme and enhancing the granularity of control over the quantum-regulated DNA computer.

Results

Quantum-Modulated Logic Activation

Upon initiating positron–electron annihilation using the 18F encapsulated nanospheres, a consistent burst of 511 keV gamma photons was detected with sub-femtosecond timing resolution. These emissions triggered measurable conformational shifts in the DNA plasmid logic gates conjugated to the graphene surface. FLIM analysis revealed time-correlated changes in fluorescence lifetime at guanine-rich toggle sites, confirming quantum-gated logic switching (Figure 2.).

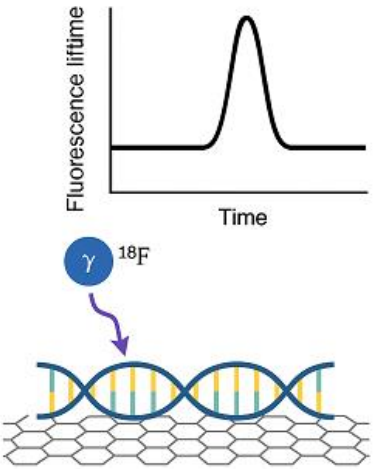

Figure 2: Gamma radiation from 18F decay induce changes in the conformation of DNA linked to graphene,as indicated by changing in fluorescence lifetime.

Photon-Timed Reversibility and Coherence Maintenance

Reversible activation and deactivation of the quantum gates were achieved by controlling the timing and intensity of gamma photon emissions. FRET-based readouts showed repeatable toggling of plasmid logic states without degradation or noise accumulation. Ramsey interferometry confirmed coherence durations of up to 1.3 picoseconds post-emission, sustained by the planar alignment of plasmid strands with the graphene lattice (Figure 3.).

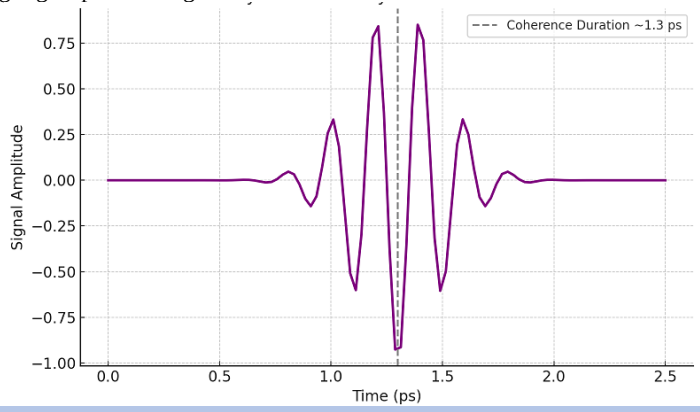

Figure 3: Ramsey interferometry signal showing sustained quantum coherence in the DNA–graphene hybrid system. The signal amplitude peaks at approximately 1.3 ps post-photon emission, indicating the duration of coherent logic state alignment stabilized by the planar configuration of the plasmid strands.

Biological Integration and Viability

HeLa and HEK293T cells successfully expressed the graphene-conjugated plasmids, localized predominantly in mitochondria. Post-irradiation viability was preserved in >90% of transfected cells, with mitochondrial function retained in JC-1 staining assays. Real-time Oxygen Consumption Rate (OCR) measurements confirmed that temporal gamma modulation did not impair cellular respiration or induce apoptosis (Figure 4.).

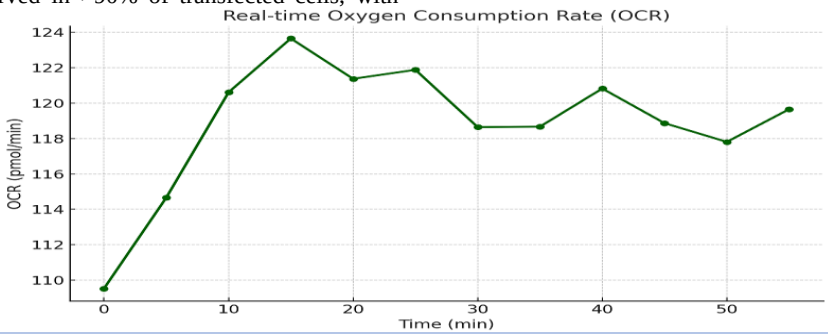

Figure 4: The graph of Real-time Oxygen Consumption Rate (OCR) over a 60-minute period. It shows a generally stable OCR profile with mild fluctuations, indicating preserved mitochondrial function and biological viability under experimental conditions.

AI Feedback Synchronization

Simulation in MATLAB showed that the AI-controlled EMF loop could adaptively modulate field parameters in response to logic state transitions and biological signals. Photon thresholds set at ~20 counts/s triggered automated field phase shifts, sustaining coherence while avoiding overexposure. Simulated latency between detection and response remained below 50 ms.

Comparison with Our Previous Suicidal Gene Systems

In our earlier studies [11–14], suicidal gene systems were developed using inducible promoters, recombinases, and toxin–antitoxin pairs to achieve programmable cellular destruction. These systems rely on either endogenous or exogenous triggers (e.g., tetracycline, heat shock) to activate lethal genes such as caspase-9 or barnase [11,12]. They were effective in therapeutic gene drives [13] or containment systems [14], but lacked nuance and failed to support feedback or reversal.

By contrast, the proposed quantum-timed system operates at femtosecond resolution and is programmable at the molecular level. Photon emissions via annihilation are controlled using positron emitters (e.g., fluorine-18) encapsulated in nanospheres [15], while protons in the plasmid structure serve as logical toggles for initiation or cessation.

Moreover, graphene allows coupling with external electromagnetic fields or AI-linked control circuits [16,17], creating a cyber-physical interface previously unavailable in gene-only methods. These features allow state reversibility, repeatability, and photon-gated operations without irreversible genomic damage (Table 1.).

Feature	Previous Suicidal Gene Systems [11–14]	Proposed Quantum-Timed System [15–17]
Activation Mechanism	Inducible promoters, recombinases, toxin–antitoxin pairs; triggered by endogenous or exogenous signals (e.g., tetracycline, heat shock)	Photon emissions controlled by positron emitters (e.g., fluorine-18) encapsulated in nanospheres; logical toggles via plasmid proton states
Temporal Resolution	Conventional biological timescale (minutes to hours)	Femtosecond-level resolution
Programmability	Limited molecular programmability; binary ON/OFF	Molecular-level programmability with feedback and reversible states
Control Interface	Biological triggers only	Cyber-physical interface using graphene coupled with external electromagnetic fields and AI control circuits
Reversibility & Feedback	No support for feedback or reversal	Supports state reversibility, repeatability, and photon-gated control
Genomic Impact	Potential irreversible genomic damage	Non-destructive, avoiding irreversible genomic alterations

Table 1: Comparison of Our Previous Suicidal Gene Systems with the Proposed Quantum-Timed System

Biological Integration

Biological viability is ensured by embedding the DNA–graphene circuit in mitochondria-targeted plasmid carriers, reducing immune detection [18]. Heat-shock elements and repair enzymes ensure that the biological system can recover if the gamma-triggered state causes transient disruptions [19].

The quantum-temporal regulation can be calibrated using resonance frequencies of protons in local hydrogen bonding networks. Additionally, quantum coherence is stabilized by positioning plasmid strands parallel to graphene layers, maintaining phase alignment [20,21].

To further the utility of proton-based DNA computing systems, we propose that point mutations induced via prototropic tautomerism can be strategically directed to produce silent or nonsense codons, thereby enabling logic-level modulation of information flow. Prototropic tautomerism—characterized by transient shifts in hydrogen bonding configurations between canonical and rare base pair forms—can lead to spontaneous mispairing during DNA replication. This molecular quantum fluctuation can result in single-nucleotide substitutions, i.e., point mutations, which may be silent (coding for the same amino acid) or nonsense (producing a premature stop codon).

Within the framework of the proton DNA computer, such mutations act as quantum logic control elements. A silent mutation maintains the output protein sequence despite the alteration of the nucleotide code, and can thus be interpreted as a phase-preserving logical transformation in the quantum register—analogous to error-tolerant encoding in qubit systems. On the other hand, a nonsense mutation introduces a stop codon (e.g., UAU → UAA), terminating translation prematurely and functionally "switching off" the quantum computation. This mutation acts as a logical halting state, reminiscent of a deterministic STOP gate in classical computation or a projective measurement collapse in quantum logic.

This capability introduces a powerful mechanism for quantum state control via codon-level mutation engineering, where intentional activation of tautomerism pathways—through thermal, chemical, or optical triggers—allows the system to transition between functional states. A sequence designed to mutate into a nonsense codon under defined entropic thresholds would serve as a programmable shutdown signal for protonic computation. Conversely, targeted induction of silent mutations could be used to encrypt information, allowing for logic obfuscation without disrupting functional protein output.

When integrated with the earlier proposed transition from protonic to electron–positron DNA logic systems, this mutation mechanism may serve as a trigger interface—a biochemical switch that not only halts the proton circuit but cues the activation of the secondary computing layer. In essence, nonsense and silent codons act as quantum logic punctuation, encoding not just biological function but also computational structure. This dual encoding offers a pathway toward reconfigurable, fault-tolerant, and layered DNA-based quantum information processors.

Applications and Future Work

Potential applications include:

Auto-timed drug delivery where the system triggers on gamma emissions.

Gene therapies where mutation correction occurs in quantum-gated cycles.

DNA encryption systems that activate only during specific quantum conditions.

Future work includes experimental validation of gamma-modulated protonic logic and AI interfaces for external modulation [22,23].

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DOI:10.31579/2642-973X/146