COHERENT FUSION REACTOR: SUPPLEMENT BASED ON BROWNIAN MOTION ANALYSIS

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ABSTRACT

A supplement to the conceptual design of the coherent fusion reactor [1] is presented, based on the results of Brownian motion analysis within ODTOE [2]. A dimensionless parameter $r = R_0^2(\pi - 3)^2\varphi^d/[2D_0(1 - S)\tau_0]$ is introduced, defining the ratio of directed drift (generated by the spiral gap) to stochastic turbulence. It is shown that the critical coherence for the transition to the drift regime for a compact reactor ($R_0 = 0.3$ m) is $S_c \approx 0.098$, which is substantially lower than for the ITER scale ($S_c \approx 0.872$). An adaptive φ-pulsation is proposed, in which the magnetic field rhythm adjusts to the current plasma coherence: at low S — a compressed rhythm ($\sqrt{\varphi}$ scaling), at high S — the standard (φ scaling). The anomalous plasma diffusion exponent $\alpha = 1 + S$ is identified as a measurable quantity, enabling its inclusion in the feedback loop. Project parameters are refined and items requiring correction are noted.

Quantitative criterion for turbulence suppression, adaptive φ-pulsation, and control of anomalous plasma diffusion.

Keywords: coherent fusion, anomalous diffusion, Hurst exponent, φ-pulsation, plasma coherence, turbulence, ODTOE, Brownian motion.

I. INTRODUCTION AND RELATION TO THE BASE PROJECT

I.1. Context

The conceptual design of the coherent fusion reactor [1] is based on three ODTOE principles: (a) resonance windows in the Coulomb barrier of width $(\pi - 3)^2 \approx 2\%$, arranged with φ-scaling; (b) ternary confinement geometry ($120° + \delta_\pi$); (c) feedback on plasma coherence S instead of feedback on temperature.

The analysis of Brownian motion in ODTOE [2] established that the Hurst exponent H of fractional Brownian motion is related to coherence by the formula $H = (1 + S)/2$, and the spiral gap $(\pi - 3)^2$ determines the parameter r — the ratio of drift to stochasticity. The present work applies these results to the plasma physics of the reactor.

I.2. List of refinements to the base project

Three items in the base project [1] have been identified as requiring refinement in light of the new results.

Item 1. Qualitative description of turbulence suppression (Section VI.6 in [1]). The statement "as $S \to 1$: $D(\eta) \to 0$, turbulence is suppressed" is correct but lacks a quantitative criterion. Refinement: the transition from the turbulent to the drift regime is determined by the parameter $r = 1$, which defines the critical coherence S_c.

Item 2. Fixed φ-pulsation (Section 3.3 in [1]). The sequence $\tau_{n+1} = \varphi \cdot \tau_n$ assumes a fixed ratio φ between pulse durations. Refinement: the ratio should adapt to the current plasma coherence, varying from $\sqrt{\varphi}$ to φ.

Item 3. Feedback on S without accounting for the diffusion exponent (Section VI.5 in [1]). The feedback loop is aimed at maximizing S. Refinement: in addition to S, it is necessary to measure the anomalous diffusion exponent α, which is an independent diagnostic parameter.

I.3. Structure of the supplement

The work is organized as follows. Section II introduces the parameter r and derives the formula for the critical coherence S_c. Section III describes the adaptive φ^H-pulsation with numerical examples and FPGA implementation requirements. Section IV establishes the connection between anomalous plasma diffusion and coherence and supplements the feedback loop. Section V systematizes plasma regimes through the Hurst exponent. Section VI contains the refined parameter table. Section VII describes the positive feedback mechanism and analyzes its stability. Section VIII compares the coherent reactor with classical approaches. Section IX supplements the experimental plan. Section X contains the demarcation, Section XI — the conclusion.

II. THE PARAMETER r AND CRITICAL PLASMA COHERENCE

II.1. Plasma turbulence as a Brownian problem

Plasma in a tokamak is a system in which chaos (turbulence) competes with order (magnetic confinement). Anomalous diffusion — the transport of particles and energy exceeding classical (collisional) transport by a factor of 10–100 — remains the main unsolved problem of controlled thermonuclear fusion [13, 14]. No existing tokamak has achieved a regime in which transport is determined solely by collisions; turbulence always dominates.

In ODTOE terms: plasma ions are observers at the atomic level ($d = 0$), united into a cluster. The collective coherence S of this cluster determines in which regime — turbulent or coherent — the system operates. The analysis of Brownian motion [2] allows reformulation of the problem: anomalous plasma diffusion is identified with fractional Brownian motion of ions at a Hurst exponent $H \neq 1/2$, caused by turbulence as a collective effect of low coherence.

The key identification: the stochastic component of an ion trajectory in the plasma (caused by turbulence) corresponds to the Brownian motion from [2], while the deterministic component (caused by magnetic confinement) corresponds to the gap drift $(\pi - 3)$. Thus, the parameter r from [2] acquires direct physical meaning: it is a measure of the relative strength of magnetic confinement compared to turbulent chaos.

II.2. Origin of the parameter r

In [2] it was established that at observation level d, the total mean square displacement consists of two components: deterministic drift (generated by the spiral gap) and stochastic noise (Brownian turbulence). The drift arises because the self-observation loop Φ does not close exactly: over each revolution of length 2π, a displacement $\Delta\varphi = \pi - 3$ accumulates along the major radius of the torus [4, formula IV.3]. At level d, the major radius of the torus equals $R_d = R_0\varphi^d$ [4, formula VI.1], so the drift scales as:

$$\Delta x_{\text{drift}}(d) = R_0(\pi - 3) \cdot \varphi^d \tag{II.1}$$

The stochastic displacement is determined by the diffusion coefficient $D(S) = D_0(1 - S)$ [3, formula 4.4a] and the characteristic time τ:

$$\Delta x_{\text{stoch}} = \sqrt{2D_0(1 - S)\tau} \tag{II.2}$$

The parameter r is the ratio of the square of the drift to the square of the stochastic displacement:

$$r(d,\, S) = \frac{R_0^2(\pi - 3)^2 \cdot \varphi^d}{2\, D_0(1 - S)\, \tau_0} \tag{II.3}$$

For $r < 1$, stochastic turbulence dominates. For $r > 1$, the directed gap drift suppresses turbulence. The factor φ^d means: the higher the observation level of the cluster, the stronger the drift and the easier it is to reach the coherent regime.

Physical interpretation: the parameter r is an analogue of the Péclet number in mass transfer theory — it characterizes the ratio of convective (directed) and diffusive (random) transport. However, unlike the classical Péclet number, r contains the fundamental ODTOE constants ($\pi - 3$, φ), which transforms this parameter from a purely empirical one into a structurally determined one.

II.3. General formula for the critical coherence

From the condition $r = 1$ (equilibrium of drift and stochasticity):

$$R_0^2(\pi-3)^2 \cdot \varphi^d = 2\,D_0(1-S_c)\,\tau_0 \tag{II.4}$$

Solving for S_c:

$$S_c(d) = 1 - \frac{R_0^2(\pi-3)^2 \cdot \varphi^d}{2\,D_0\,\tau_0} \tag{II.5}$$

The formula contains: three measurable parameters (R_0, D_0, τ_0), the fundamental ODTOE constant $(\pi - 3)^2$, the scaling factor φ^d (a consequence of the toroidal hierarchy), and the cluster dimensionality d. With increasing d (a more coherent, higher-level cluster), the factor φ^d grows, the numerator increases, and S_c decreases: it is easier for a coherent cluster to transition to the drift regime.

Additional analysis: formula (II.5) can be written in logarithmic form, convenient for graphical analysis:

$$\ln(1-S_c) = 2\ln R_0 + 2\ln(\pi-3) + d\ln\varphi - \ln(2D_0\tau_0) \tag{II.6}$$

The dependence of $\ln(1-S_c)$ on d is linear with slope $\ln\varphi \approx 0.481$. This prediction is testable: if a coherent reactor is implemented, the dependence of S_c on the effective cluster dimensionality should follow (II.6).

II.4. Special case: plasma ions ($d = 0$)

Plasma ions are observers at the atomic level ($d = 0$) [3, Section IV.2]. For $d = 0$: $\varphi^0 = 1$, and the formulas simplify:

$$r(S) = \frac{R_0^2(\pi-3)^2}{2\,D_{\text{anom}}(1-S)\,\tau_E} \tag{II.7}$$

$$S_c = 1 - \frac{R_0^2(\pi-3)^2}{2\,D_{\text{anom}}\,\tau_E} \tag{II.8}$$

where D_{anom} is the anomalous diffusion coefficient, τ_E is the energy confinement time.

We denote the dimensionless design parameter of the reactor:

$$\kappa = \frac{R_0^2(\pi-3)^2}{2\,D_{\text{anom}}\,\tau_E} \tag{II.9}$$

Then $S_c = 1 - \kappa$ and $r(S) = \kappa/(1-S)$. For $\kappa > 1$, the gap drift dominates for any $S > 0$. For $\kappa < 1$, coherence $S > S_c = 1 - \kappa$ is required.

Remark: if the ion cluster achieves collective coherence, its effective dimensionality increases ($d > 0$), $\varphi^d > 1$, and the critical coherence is further reduced. This effect creates positive feedback (Section VII).

II.5. Numerical estimates

Coherent reactor (parameters from [1]): $R_0 = 0.3$ m, $D_{\text{anom}} = 1$ m^2/s, $\tau_E = 10^{-3}$ s.

$$\kappa = \frac{(0.3)^2 \times 0.020048}{2 \times 1 \times 10^{-3}} = \frac{0.0018043}{0.002} = 0.9022 \tag{II.10}$$

$$S_c = 1 - 0.9022 = 0.098 \tag{II.11}$$

ITER: $R_0 = 6.2$ m, $D_{\text{anom}} = 1$ m^2/s, $\tau_E = 3$ s.

$$\kappa = \frac{(6.2)^2 \times 0.020048}{2 \times 1 \times 3} = \frac{0.7703}{6} = 0.1284 \tag{II.12}$$

$$S_c = 1 - 0.1284 = 0.872 \tag{II.13}$$

Result: for a compact reactor ($R_0 = 0.3$ m), $S_c \approx 0.10$. For ITER ($R_0 = 6.2$ m), $S_c \approx 0.87$. Reducing the scale facilitates achieving the coherent regime: compactness is not a limitation but an advantage.

II.6. Comparative analysis of κ at various scales

For a systematic assessment of the reactor scale's influence on the critical coherence, consider a series of devices with different R_0:

Table 1: Dependence of the design parameter κ and critical coherence S_c on reactor scale at $D_{\text{anom}} = 1$ m^2/s

Device	R_0, m	τ_E, s	κ	S_c
Tabletop fusor	0.05	10^{-4}	0.250	0.750
Compact reactor	0.30	10^{-3}	0.902	0.098
Medium tokamak	1.00	0.10	0.100	0.900
KSTAR	1.80	0.50	0.065	0.935
JET	2.96	1.00	0.088	0.912
ITER	6.20	3.00	0.128	0.872

From Table 1 it is evident that κ does not depend monotonically on R_0, since τ_E also increases with scale (approximately as $\tau_E \propto R_0^{1.5-2}$). The best value of κ (largest, close to unity) is achieved for the compact reactor: it is precisely at this point in parameter space that the ratio R_0^2/τ_E is maximized.

Engineering consequence: instead of the abstract requirement "increase S", the reactor control system receives a concrete numerical threshold — "achieve $S > S_c$", where S_c is computed from measurable chamber parameters (R_0, D_{anom}, τ_E). The coherent reactor controls not temperature but the parameter S, and through it — the anomalous diffusion exponent α. This is a fundamentally different control strategy compared to the classical Lawson criterion $nT\tau$.

II.7. Remark on D_{anom}

The anomalous diffusion coefficient D_{anom} in real plasma devices varies by orders of magnitude depending on the regime. The empirical Bohm scaling $D_{\text{Bohm}} \sim T_e/(16eB)$ yields $D \sim 1$ m^2/s for typical parameters. The coherent reactor, however, is aimed at reducing D_{anom} through increasing S, which creates positive feedback: increase in S $\rightarrow$ decrease in D_{anom} $\rightarrow$ increase in r $\rightarrow$ enhancement of drift $\rightarrow$ further increase in S.

Quantitative estimate of D_{anom} reduction: within ODTOE, $D_{\text{anom}} = D_0(1-S)$, so upon reaching $S = 0.5$, anomalous diffusion is halved, and at $S = 0.9$ it decreases by an order of magnitude. Connection to Bohm scaling: $D_{\text{Bohm}}(S) = D_{\text{Bohm},0}(1-S)$, which predicts a deviation from classical Bohm scaling for coherent plasma.

II.8. Dependence of r on the magnetic field

In explicit form, the Bohm anomalous diffusion coefficient contains the magnetic field: $D_{\text{Bohm}} = T_e/(16eB)$. Substituting into (II.7):

$$r(S, B) = \frac{16\, e\, B\, R_0^2(\pi - 3)^2}{2\, T_e(1 - S)\, \tau_E} \tag{II.14}$$

Therefore, r grows linearly with the magnetic field B. This is consistent with the intuitive expectation: strengthening the magnetic field suppresses turbulence. However, in the coherent reactor the main control parameter is not B but S: increasing S exponentially increases r through the denominator $(1 - S)$, whereas increasing B does so only linearly. This fundamental difference determines the coherent reactor strategy.

III. ADAPTIVE φ-PULSATION

III.1. The problem

In the base project [1, Section 3.3], the magnetic field pulsates with a fixed ratio $\tau_{n+1}/\tau_n = \varphi$. The analysis of Brownian motion [2] reveals the physical meaning of this pulsation: the φ-rhythm is not an arbitrary choice but a resonant suppression of the fractality of ion trajectories. In the stochastic (turbulent) regime, ion trajectories are fractal (Hausdorff dimension $d_H = (3 - S)/2 \approx 1.5$ at $S \approx 0$). The φ-pulsation transitions ions to a regime with reduced fractality ($d_H \rightarrow 1$ as $S \rightarrow 1$), where trajectories straighten and ions enter the resonance window of the Coulomb barrier.

An analogy from quantum biology: quantum coherence in photosynthesis [15] allows the exciton to find the optimal path through the antenna complex with efficiency close to 100% at room temperature. Coherent plasma similarly “finds” the resonance windows in the Coulomb barrier — not through brute-force heating but through coordinated ion motion.

The scaling factor between observation levels depends on coherence [2]:

$$\sqrt{\lambda(S)} = \varphi^{H(S)}, \quad H(S) = \frac{1+S}{2} \tag{III.1}$$

At low S (reactor startup): $H \approx 0.5$, scaling factor $\approx \sqrt{\varphi} \approx 1.272$.

At high S (operating regime): $H \to 1$, scaling factor $\to \varphi \approx 1.618$.

The fixed φ-pulsation is optimal only in the operating regime, but not during the ramp-up phase. With φ-pulsation, the reactor establishes resonance between the temporal scale of the perturbation and the natural scale of the toroidal hierarchy [4]: each pulse in the sequence $\tau_0,\ \varphi\tau_0,\ \varphi^2\tau_0,\ \ldots$ is addressed to a specific level of nested tori, and the perturbation efficiency is maximal when the duration ratio matches the scaling factor φ^H.

III.2. Proposal

Replace the fixed φ-pulsation with an adaptive one:

$$\tau_{n+1} = \varphi^{H(S_{\text{current}})} \cdot \tau_n \tag{III.2}$$

where S_{current} is the measured plasma coherence in real time. During the ramp-up phase (S is small): $\tau_{n+1}/\tau_n \approx \sqrt{\varphi} \approx 1.272$ — more frequent pulses. In the operating phase (S is high): $\tau_{n+1}/\tau_n \approx \varphi \approx 1.618$ — the standard φ-rhythm.

Formula (III.2) ensures a continuous transition between the two limiting regimes, with the transition determined not by a preset program but by the current state of the plasma. This is a key distinction from standard ramp-up scenarios in tokamaks, where the heating phase sequence is fixed by the operator.

III.3. Connection to the Hausdorff dimension of trajectories

The Hausdorff dimension of ion trajectories is determined by the Hurst exponent [6]:

$$d_H = \frac{1}{H} = \frac{2}{1+S} \tag{III.3}$$

At $S = 0$: $d_H = 2$ (planar Brownian trajectory). At $S = 1$: $d_H = 1$ (ballistic straight line). The adaptive pulsation selects a temporal scale matched to the current fractal dimension of the trajectories, ensuring maximum resonant response of ions at each stage of reactor operation.

Connection between d_H and the efficiency of entering the resonance window $(\pi - 3)^2$: as $d_H \to 1$, the ion trajectory straightens, and the probability of entering the narrow window of width $(\pi - 3)^2 \approx 2\%$ increases. Estimate: the entry probability scales as $P_{\text{window}} \sim (\pi - 3)^{2(d_H - 1)}$, which for $d_H = 1.5$ gives $P \sim 14\%$, and for $d_H = 1.1$ already $P \sim 72\%$.

III.4. Implementation

The FPGA controller (envisaged in [1, Section 3.3]) takes as input the current value of S from the coherence spectrometer and computes $H = (1 + S)/2$. The multiplier φ^H is computed via a lookup table or series: $\varphi^H = \exp(H \cdot \ln \varphi)$, where $\ln \varphi = 0.48121$ (stored as a constant). It then generates a pulse sequence with an adaptive duration ratio.

Additional requirement for the FPGA firmware: computation of φ^H with precision no less than 10^{-4} (a third-order Taylor polynomial for exp is sufficient).

FPGA implementation specification:

(a) Input signal: $S \in [0;\, 1]$, 16-bit fixed-point representation (Q1.15).

(b) Computation of H: one addition and one shift ($H = (1 + S) \gg 1$), latency 1 clock cycle.

(c) Computation of φ^H: CORDIC table or third-order Taylor polynomial for exp$(H \cdot 0.48121)$, latency no more than 10 clock cycles.

(d) Output signal: duration of the next pulse τ_{n+1}, 32-bit representation, transmitted to the pulse generation timer.

(e) Total latency: no more than 20 clock cycles at 100 MHz, corresponding to a delay of 200 ns — negligible compared to characteristic plasma process times (μs–ms).

III.5. Numerical example

Startup phase: $S = 0.05$, $H = 0.525$, $\varphi^H = 1.282$.

Sequence from $\tau_0 = 1$ ms: $1.000 \to 1.282 \to 1.643 \to 2.106 \to 2.700 \to 3.461$ ms.

Operating regime: $S = 0.50$, $H = 0.750$, $\varphi^H = 1.435$.

Sequence from $\tau_0 = 1$ ms: $1.000 \to 1.435 \to 2.059 \to 2.954 \to 4.238 \to 6.082$ ms.

Limiting regime: $S = 0.90$, $H = 0.950$, $\varphi^H = 1.580$.

Sequence from $\tau_0 = 1$ ms: $1.000 \to 1.580 \to 2.496 \to 3.943 \to 6.230 \to 9.843$ ms.

Table 2: Adaptive pulsation parameters for various coherence values

S	H	φ^H	d_H	τ_5/τ_0
0.00	0.500	1.272	2.000	3.30
0.05	0.525	1.282	1.905	3.46
0.20	0.600	1.326	1.667	4.13
0.50	0.750	1.435	1.333	6.08
0.70	0.850	1.510	1.176	7.82
0.90	0.950	1.580	1.053	9.84
1.00	1.000	1.618	1.000	11.09

IV. ANOMALOUS PLASMA DIFFUSION AS A DIAGNOSTIC PARAMETER

IV.1. Relation between anomalous diffusion and coherence

As established in Section II.1, anomalous plasma diffusion is identified with fractional Brownian motion of ions governed by coherence S. From [2]: MSD $\sim t^{\alpha}$, where $\alpha = 1+S$. The anomalous diffusion exponent α is measurable through correlation analysis of plasma density fluctuations.

At $\alpha = 1$ ($S = 0$): normal diffusion, classical turbulence.

At $\alpha > 1$ ($S > 0$): superdiffusion, collective modes, ballistic transport.

At $\alpha < 1$ ($S < 0$, formally): subdiffusion, traps, reduced transport.

IV.2. Connection to reaction kinetics

The reconfiguration rate (in particular, the fusion reaction rate) obeys the generalized Kramers formula [8]:

$$v_{\text{reconf}} = v_0 \cdot \exp\left(-\frac{I(C)}{D_0(1-S)}\right) \tag{IV.1}$$

where $I(C)$ is the configuration inertia (analogue of the Coulomb barrier height), $D_0(1-S)$ is the effective "temperature" of stochasticity. As $S \to 1$, the effective temperature tends to zero, but ions coherently enter the resonance window, and the factor $1/(\pi-3)^2 \approx 50$ [1] compensates for the exponential suppression.

The task of the coherent reactor is not to suppress diffusion entirely ($S \to 1$ is unattainable by Statement 3 [3]) but to tune the exponent α to the optimal value at which ions enter the resonance window $(\pi-3)^2$ of the Coulomb barrier. The optimal value is determined by the condition $\alpha \to 1 + S_{\text{target}}$, where S_{target} corresponds to the maximum tunneling probability through the resonance window.

Expansion of the Kramers formula near the optimum: let $S = S_{\text{target}} + \delta S$, then

$$v_{\text{reconf}} \approx v_0 \exp\left(-\frac{I(C)}{D_0(1-S_{\text{target}})}\right)\left[1 + \frac{I(C)\,\delta S}{D_0(1-S_{\text{target}})^2} + O(\delta S^2)\right] \tag{IV.2}$$

The linear sensitivity of the reaction rate to δS is determined by the parameter $I(C)/[D_0(1-S_{\text{target}})^2]$. For the Coulomb barrier of the D-D reaction at $S_{\text{target}} \sim 0.5$: $I(C) \sim 10$ keV, $D_0(1-S_{\text{target}}) \sim 0.5$ m^2/s, yielding high sensitivity — a change in S by 0.01 changes the reaction rate by several percent.

IV.3. Supplement to the feedback loop

In the base project [1, Section VI.5], the feedback loop measures coherence S through correlation spectroscopy and adjusts the phase shifts of the magnetic coils.

Supplement: in parallel with S, measure the anomalous diffusion exponent α. Technically, this is implementable through correlation function analysis of plasma density fluctuations — a technique already employed in tokamak turbulence diagnostics [13, 14]. Specific steps:

(a) Analysis of time series of plasma density fluctuations (probe diagnostics or reflectometry).

(b) Computation of MSD from the correlation function: $C(\tau) = \langle n(t+\tau)\, n(t)\rangle$.

(c) Determination of α from the slope of $\ln \mathrm{MSD}(\tau)$ vs $\ln \tau$.

FPGA operating algorithm:

1. Measure S (correlation spectroscopy).

2. Measure α (MSD analysis of density fluctuations).

3. Check consistency: $\alpha \approx 1 + S$ (if discrepancy $> 10\%$ — diagnostic signal of an off-normal regime).

4. Compute $H = (1 + S)/2$.

5. Adjust φ-pulsation: $\tau_{n+1} = \varphi^H \cdot \tau_n$.

6. Adjust coil phase shifts, aiming for $\alpha \to 1 + S_{\text{target}}$, where S_{target} corresponds to entering the resonance window $(\pi - 3)^2$.

IV.4. Methods of measuring α in plasma experiments

The anomalous diffusion exponent α can be measured by several independent methods:

Method 1. Probe diagnostics (Langmuir probe). The time series of the ion saturation current $I_{\text{sat}}(t)$ is recorded at a sampling rate ≥ 1 MHz. MSD is computed: $\mathrm{MSD}(\tau) = \langle [I_{\text{sat}}(t+\tau) - I_{\text{sat}}(t)]^2\rangle$. The slope of $\ln \mathrm{MSD}$ vs $\ln \tau$ yields α. Advantage: simplicity and low cost. Limitation: the probe perturbs the plasma.

Method 2. Reflectometry. A microwave beam reflects from the critical density layer. Phase fluctuations of the reflected signal contain information about density fluctuations. MSD analysis of the phase yields α. Advantage: non-invasive method. Limitation: requires calibration.

Method 3. Correlation spectroscopy of scattered radiation. The turbulence spectral index γ is related to α: $\gamma = 1 + \alpha$ [14]. Measurement of the density fluctuation spectrum through scattering of microwaves or laser radiation allows determination of γ, and through it — α. Advantage: provides spatial resolution. Limitation: requires a complex optical system.

V. PLASMA REGIMES THROUGH THE HURST EXPONENT

Systematization of plasma regimes in ODTOE terms:

Table 3: Plasma regimes and control system actions

α	H	S	Plasma regime	Control system action
< 0.7	< 0.35	< -0.30	Subdiffusion (traps)	Increase heating power
$0.7–1.0$	$0.35–0.50$	$-0.30–0$	Normal turbulence	Increase S via φ-pulsation
$1.0–1.3$	$0.50–0.65$	$0–0.30$	Weak coherence	Continue increasing S
$1.3–1.7$	$0.65–0.85$	$0.30–0.70$	Transitional regime	Adapt rhythm to φ^H
$1.7–2.0$	$0.85–1.00$	$0.70–1.00$	Coherent plasma	Operating regime, $(\pi - 3)^2$ window

Each regime is characterized by qualitatively different transport physics. In the subdiffusion regime ($\alpha < 0.7$), ions become “trapped” in magnetic traps, indicating a suboptimal magnetic field configuration. In the normal turbulence regime ($\alpha \approx 1$), transport obeys the classical diffusion law. In the transitional regime ($\alpha \sim 1.5$), collective modes begin to manifest, signaling the onset of coherence. In the operating regime ($\alpha > 1.7$), transport is ballistic: ions move collectively, in concert, ensuring entry into the resonance window of the Coulomb barrier.

The transition between regimes is not abrupt but continuous, as determined by the continuous dependence $\alpha = 1 + S$. However, the qualitative change in transport physics upon crossing the threshold S_c (transition of r through unity) creates an effective “phase transition” of the plasma from the turbulent to the coherent state.

VI. REFINED PARAMETER TABLE

Update of the table from [1, Section VI.7] with account of the new results:

Table 4: Comparison of parameters: ITER, base project, and refined project

Parameter	ITER	Base project [1]	Refined project
R_0	6.2 m	0.3–1 m	0.3–1 m (unchanged)
Barrier crossing	Heating to 10^8 K	Resonance $(\pi - 3)^2$	Resonance $(\pi - 3)^2$ (unchanged)
Geometry	Toroidal	Ternary	Ternary (unchanged)
Pulsation	None	φ-puls. (fixed)	Adaptive φ^H-pulsation
Feedback	T, p, n_e	Coherence S	S + exponent α
Regime criterion	$nT\tau > 3 \times 10^{21}$	$S > S_c$	$S > S_c$ and $\alpha > 1.3$
S_c	Not applicable	Not defined	0.10 (at $R_0 = 0.3$ m)
κ	0.128	Not defined	0.902 (at $R_0 = 0.3$ m)
α diagnostics	None	None	MSD analysis of fluctuations

VII. POSITIVE FEEDBACK MECHANISM

VII.1. Description of the mechanism

Analysis of the parameter r reveals a self-reinforcing coherence mechanism not noted in the base project.

Starting state: S is small, $r < 1$, turbulence dominates.

Step 1: φ^H-pulsation creates a resonant perturbation at the scale corresponding to the current H.

Step 2: Even a small increase in S reduces $D_{\text{anom}} = D_0(1 - S)$ and increases r.

Step 3: At $r > 1$, the gap drift begins to suppress turbulence.

Step 4: Suppression of turbulence increases S (ions become more coherent).

Step 5: The increase in S increases H, and the adaptive pulsation transitions to longer (φ-scaled) pulses.

Step 6: Longer coherent pulses suppress turbulence more effectively.

The positive feedback continues until the operating regime ($S \sim 0.5$–0.7) is reached, after which the system stabilizes at a level determined by losses.

VII.2. Mathematical model of $S(t)$ dynamics

The coherence dynamics can be described by a first-order differential equation:

$$\frac{dS}{dt} = \gamma_+(S) - \gamma_-(S) \tag{VII.1}$$

where $\gamma_+(S)$ is the rate of coherence growth due to φ^H-pulsation and gap drift, $\gamma_-(S)$ is the rate of coherence loss due to collisions and energy losses.

For the simplest model: $\gamma_+(S) = \gamma_0 \cdot r(S) = \gamma_0\kappa/(1 - S)$, $\gamma_-(S) = \nu \cdot S$, where γ_0 is the characteristic coherentization rate, ν is the decoherence frequency. The stationary state is determined by the equation:

$$\frac{\gamma_0\kappa}{1 - S^*} = \nu S^* \tag{VII.2}$$

This is a quadratic equation in S^*:

$$\nu(S^*)^2 - \nu S^* + \gamma_0\kappa = 0 \tag{VII.3}$$

$$S^* = \frac{1}{2}\left(1 - \sqrt{1 - 4\gamma_0\kappa/\nu}\right) \tag{VII.4}$$

A stationary state exists for $4\gamma_0\kappa/\nu < 1$. For $4\gamma_0\kappa/\nu > 1$, coherence grows without bound — this is a potential disruption regime requiring a limiter.

VII.3. Stability and the limiter

Risk: uncontrolled growth of S can lead to plasma loss (analogous to a disruption in a tokamak). The control system must include a limiter: when $S > S_{\text{max}}$ (set by the operator), pulsation switches to a stabilizing mode.

Limiter algorithm:

(a) At $S < S_c$: ramp-up mode, φ^H-pulsation with $H = (1 + S)/2$.

(b) At $S_c \leq S \leq S_{\text{max}}$: operating mode, adaptive pulsation, feedback loop active.

(c) At $S > S_{\text{max}}$: stabilizing mode, pulsation frequency resets to $\sqrt{\varphi}$-scaling (as during startup), reducing the coherentization rate.

(d) At $S > S_{\text{crit}}$ (emergency threshold): full pulsation shutdown, coil current dump.

Numerical values for the compact reactor: $S_c = 0.10$, $S_{\text{max}} = 0.80$, $S_{\text{crit}} = 0.95$.

VIII. COMPARISON WITH CLASSICAL APPROACHES

VIII.1. The Lawson criterion vs the coherence criterion

The classical ignition criterion for a fusion reaction (Lawson criterion) requires:

$$n\,T\,\tau_E > 3 \times 10^{21}\ \text{m}^{-3} \cdot \text{keV} \cdot \text{s} \tag{VIII.1}$$

The coherent reactor proposes an alternative criterion:

$$S > S_c = 1 - \kappa, \quad \alpha > 1 + S_c \tag{VIII.2}$$

The key difference: the Lawson criterion requires simultaneously achieving high density, high temperature, and long confinement time. The coherence criterion requires a single parameter — coherence S exceeding the threshold S_c. Temperature, density, and confinement remain important, but their role shifts from “necessary condition” to “initial conditions”.

VIII.2. Comparison of control strategies

Table 5: Comparison of control strategies: classical vs coherent

Characteristic	Classical tokamak	Coherent reactor
Controlled quantity	T, n_e, I_p	S, α
Ignition criterion	$nT\tau > 3 \times 10^{21}$	$S > S_c$
Heating strategy	Ohmic + NBI + ECRH	φ^H-pulsation
Turbulence control	Flow shear, transport barriers	Coherent suppression

Characteristic	Classical tokamak	Coherent reactor
Feedback	PID on T, n_e, β	Adaptive φ^H on S, α
Scale	Large ($R_0 > 5$ m)	Compact ($R_0 \sim 0.3$ m)
Energy cost	Tens of MW for heating	Determined by FPGA pulsation

VIII.3. Analogy with the H-mode

In classical tokamaks, the transition from L-mode (low confinement mode) to H-mode (high confinement mode) occurs upon reaching a heating power threshold. H-mode is characterized by the formation of a transport barrier at the plasma edge and a reduction of turbulent transport by a factor of 2–3 [14].

In ODTOE terms: the L-H transition is a transition through S_c, at which r exceeds unity and the gap drift begins to suppress turbulence. The formation of the transport barrier is a manifestation of coherent ions "aligning" along drift trajectories, creating an ordered layer. If this interpretation is correct, then S_c for the L-H transition can be estimated from the parameters of a specific tokamak using formula (II.8).

IX. SUPPLEMENT TO THE EXPERIMENTAL PLAN

IX.1. Stage 0 (supplement)

To the analysis of the ENDF/EXFOR databases [1, Section X], add: analysis of the anomalous diffusion exponent α in published data on plasma turbulence in tokamaks and stellarators. Check whether α correlates with confinement parameters (τ_E, β, q-factor).

Specific task: collect data on measurements of H (Hurst exponent) in plasma experiments. The literature on plasma turbulence contains measurements of spectral indices that are related to H. If a correlation of H with the q-factor (proximity to φ) is found, this would be indirect confirmation of the ODTOE approach.

Cost: 0 (data analysis). Timeline: 1–2 months.

IX.2. Stage 1 (supplement)

To the fusor with φ-pulsation [1, Section X], add: measurement of the anomalous diffusion exponent α through analysis of discharge current fluctuations. Modern oscilloscopes (bandwidth > 1 GHz, cost ~ 2000 EUR) allow recording time series with sufficient resolution.

Falsifiable prediction F9: the exponent α correlates with the phase of φ-pulsation. At moments when the pulsation rhythm coincides with the φ^H-scale, α increases (coherence grows).

Experimental protocol:

(a) Set up the fusor with φ-pulsation according to the specification in [1].

(b) Record the discharge current time series $I(t)$ at a sampling rate of 10 MHz over 100 pulses.

(c) For each pulse, compute MSD and determine α.

(d) Plot the dependence of α on the pulse number in the φ-sequence.

(e) Test the hypothesis: α is maximal when τ_{n+1}/τ_n is closest to φ^H for the current S.

Additional equipment: recording oscilloscope (~ 2000 EUR), Langmuir probe (~ 500 EUR). Total supplement to Stage 1 budget: 2500 EUR.

IX.3. Stage 2 (supplement)

Implementation of adaptive φ^H-pulsation instead of fixed φ-pulsation. FPGA firmware update (software modification, cost ~ 0). Addition of an α measurement channel to the feedback loop.

Falsifiable prediction F10: adaptive φ^H-pulsation yields a higher neutron output (in the D-D reaction) than fixed φ-pulsation, all other conditions being equal.

Experimental protocol:

(a) Run a series of $N = 50$ discharges with fixed φ-pulsation, measure the neutron yield Y_{fixed}.

(b) Run a series of $N = 50$ discharges with adaptive φ^H-pulsation, measure the neutron yield Y_{adaptive}.

(c) Statistical criterion: Student's t-test, significance level $p < 0.05$.

(d) Prediction: $Y_{\text{adaptive}}/Y_{\text{fixed}} > 1.2$ (minimum detectable effect).

IX.4. Summary table of experimental stages

Table 6: Summary of experimental program stages (supplements)

Stage	Task	Budget, EUR	Timeline
0	Analysis of α in published data	0	1–2 mo.
1	Measurement of α in fusor with φ-puls.	2 500	3–6 mo.
2	Adaptive φ^H-pulsation, test F10	~ 0	1–2 mo.

X. DEMARCATION

Table 7: Demarcation of claims

Claim	Status
$H(S) = (1+S)/2$	Hypothesis, verified on synth. data [2]
$r = R_0^2(\pi-3)^2\varphi^d/[2D_0(1-S)\tau_0]$	Follows from ODTOE + BM theory [2]
$S_c \approx 0.10$ for $R_0 = 0.3$ m	Estimate, depends on D_{anom}
Adaptive φ^H-pulsation is more effective	Falsifiable prediction (F10)
α correlates with pulsation phase	Falsifiable prediction (F9)
Positive feedback $S \to r \to S$	Hypothesis, testable at Stage 2
Resonance windows of width $(\pi-3)^2$	Hypothesis from [1], not affected
Ternary geometry	Hypothesis from [1], not affected
L-H transition as $r = 1$	New hypothesis, testable at Stage 0

XI. CONCLUSION

The analysis of Brownian motion in ODTOE [2] yielded three concrete supplements to the coherent reactor design.

First: a quantitative criterion for the transition to the coherent regime ($r = 1$, $S > S_c$). For a compact reactor ($R_0 \sim 0.3$ m), $S_c \approx 0.10$ — substantially lower than for the ITER scale ($S_c \approx 0.87$). Compactness facilitates the achievement of coherence. A dimensionless design parameter $\kappa = R_0^2(\pi-3)^2/(2D_{\text{anom}}\tau_E)$ is introduced, enabling comparison of different devices.

Second: adaptive φ^H-pulsation, in which the magnetic field rhythm adjusts to the current coherence. It is implemented through a software modification of the FPGA without hardware changes. The scaling factor continuously varies from $\sqrt{\varphi} \approx 1.272$ (startup phase) to $\varphi \approx 1.618$ (operating regime) via the formula $\varphi^{(1+S)/2}$.

Third: the anomalous diffusion exponent $\alpha = 1 + S$ as a measurable diagnostic parameter. It adds a second feedback channel, allowing control of the plasma regime and detection of off-normal situations. Three independent methods of measuring α (probe diagnostics, reflectometry, correlation spectroscopy) provide diagnostic redundancy.

All three supplements are consistent with the base project [1] and do not require revision of its architecture: the resonance windows $(\pi-3)^2$, ternary geometry, and coherence feedback on S remain the foundation. The supplements refine the parameters and expand the diagnostics.

The positive feedback mechanism ($S \to r \to S$) points to the possibility of "coherent ignition" — self-sustaining growth of coherence upon exceeding the threshold S_c. The mathematical model (VII.1)–(VII.4) determines the conditions for the existence of a stationary state and the necessity of a limiter to prevent coherent disruption.

The proposed interpretation of the L-H transition as a crossing of S_c connects the ODTOE approach to the extensive body of experimental tokamak data and can be tested at Stage 0 of the experimental program.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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