From Counts to Observables

A measurement discipline for discrete record-based physics

David Elliman
Neuro-Symbolic Ltd
dave@neusym.ai
https://neusym.ai

Draft: 2 July 2026

Abstract

Discrete record-based models of physics naturally produce integer counts: numbers of states, channels, syndromes, loops, contacts, or admissible records. Those counts can be powerful, but they also create a specific failure mode: nearby numerical coincidences may be over-promoted into physical predictions. This paper proposes a measurement discipline for such models. A *record* specifies what can be stably written, checked, copied, or protected; an *observable* is obtained only after a response map proves that an experimental apparatus reads that record. Formally, the promotion from count to observable is expressed through a closed-record response functional $Z[J_+, J_-]$, whose derivatives define measured currents, residues, fluxes, cross-sections, spectra, pole masses, or likelihoods. The purpose of the rule is not to protect the finite-QEC substrate programme from failure, but to make it easier to refute: a count that lacks the appropriate response map is demoted, while a response calculation that disagrees with experiment kills the corresponding branch. The discipline now has an operator core, proved on explicit finite models: recorded insertions carry exactly zero retarded (commutator) component, recorded coincidences factorize at diagonal Born weights, and no operation applied after a record is written can alter the recorded count — while the same operation shifts the response kernel at order one. Counters are dressing-blind; only response kernels acquire radiative dressing. Worked examples are given for occupancy versus monitored current, the bare and dressed fine-structure constant, a Newton's-constant prediction armed by the counter/kernel split, black-hole Hawking flux, the CMB/halo sector, strong-sector Wilson loops, and the electroweak pole-mass ledger. The conclusion is methodological: finite record-based physics becomes scientific only when it states not merely what the substrate can count, but which response a real experiment measures.

Plain summary

A finite information model can count many things. It can count allowed states, forbidden states, channels, links, contacts, repairs, and erasures. Some of those counts may land close to real physical constants. That is exciting, but dangerous. The count might be meaningful, or it might be numerology.

This paper states the rule I now think is essential:

A finite count is not a physical prediction until the response map proves that an experiment reads it.

The rule is deliberately severe. It demotes attractive near-hits when they are the wrong observable. It forces black-hole flux to be derived from a thermal response, not only from a horizon count. It forces the fine-structure constant to be a current residue, not merely the number 137. It forces

CMB claims to pass through a Boltzmann likelihood, QCD claims through Wilson-loop scale setting, and electroweak masses through pole matching.

This does not prove the framework. It makes it harder to fool.

The rule also has a precise quantum-mechanical core, proved on small explicit models in Section 4: once an event has been recorded, nothing that happens afterwards can change the recorded count, while the response of the same channel is suppressed exactly in proportion to how much coherence the record leaves behind. Counting and responding are different operations, and only the second one is renormalized.

1 Motivation: the anti-numerology problem

Any theory whose primitive objects are finite and combinatorial faces a particular problem. It can count many things. If one searches long enough, a count, ratio, or simple function of counts may lie near a known physical constant. This is not automatically empty: many exact physical results *are* group-theoretic, topological, or combinatorial. But it is not automatically evidence either.

The finite-QEC substrate programme is a useful test case because it has both features. Some results are genuinely record-level: code dimensions, anomaly cancellations, singlet-selection rules, and finite graph incidences. Other quantities are not record-level objects at all. They are measured through responses: a charge residue, a scattering amplitude, a flux, a pole mass, a cosmological likelihood, or a continuum string tension.

The distinction is familiar in ordinary physics. A spring can be described by its length, material, and number of coils, but its stiffness is measured by pulling it:

$$F = kx.$$

A resistor can be described by its shape and material, but its resistance is measured by putting it into a circuit:

$$V = IR.$$

The physical number is not just a stored fact; it is how the system responds to a probe.

The same distinction is needed in discrete record-based physics. The record layer tells us what can be stably represented. The response layer tells us what an experiment reads.

The vocabulary of records is not new. The it-from-bit programme proposed information as the physical primitive [38]; Landauer's principle made record erasure a physical cost [26]; and the decoherence programme identified stability under copying — pointer states, einselection, quantum Darwinism — as the criterion for which quantum states can function as classical records [41–43]. What this paper adds is not a new record concept but a discipline for the step that follows: connecting a record inventory to laboratory numbers.

Definition 1 (Discrete record-based model)**.** *A* discrete record-based model *is a model in which the primitive objects are a finite set of stable, copyable records together with rules for writing, repairing, erasing, and reading them. In the finite-*QEC *substrate programme, the elementary record is an eight-bit error-protected cell; legal patterns are particle records, illegal patterns are excluded by the code, and service events are part of the dynamics [12, 14, 15].*

Definition 2 (Record fact versus response observable)**.** *A* record fact *is a property of the finite record algebra: a dimension, a codeword count, a syndrome, an incidence relation, a symmetry representation, or an allowed/forbidden state. A* response observable *is a quantity read by an apparatus through a perturbation and a response map: a current, residue, propagator pole, flux, cross-section, Wilson loop, or likelihood.*

A complementary question is why the response layer should be quantum mechanical at all. The operational reconstructions of quantum theory [6, 18, 31] derive the Hilbert-space formalism from information-processing axioms (local tomography, purification, continuous reversibility, and their relatives). Those results are natural companions of the record-reconstruction programme: they say that once a physical theory supports the relevant operational primitives, the response formalism used below — states, effects, unitary dressing, commutator response — is forced rather than chosen. The present discipline sits one level above: *given* that formalism, it says which of a finite model's numbers an experiment actually reads.

2 The response functional

The formal object behind the discipline is a closed-record response functional, analogous in spirit to Schwinger–Keldysh closed-time path methods [5, 17, 22, 33]. In a record-based theory the histories are not only field histories but service histories: monitored sequences of record writes, repairs, erasures, and readouts.

For readers meeting closed-time-path methods for the first time, the doubling (h_+, h_-) is nothing exotic. A probability is an amplitude times a conjugate amplitude, so any generating functional for *measured* quantities must evolve a ket branch $(+)$ and a bra branch $(-)$ and couple sources to each separately [21, 34]. Two independent sources give two independent second derivatives: the symmetric (anticommutator) combination is the *noise* — the counting statistics of the record observable — while the antisymmetric (commutator) combination, taken with a retarded step function, is the *response kernel*: what moves when the system is pushed. The fluctuation–dissipation theorem is the statement that in thermal equilibrium the two are locked together [24, 25, 29]. Away from equilibrium, and in monitored record dynamics especially, they separate — and Section 4 shows the separation becomes extreme: a perfectly recorded channel keeps its full counting statistics while its commutator response vanishes identically.

Schematically,

$$Z[J_+, J_-] = \sum_{h_+,h_-} \exp\{\mathrm{i}A[h_+] - \mathrm{i}A[h_-] - A_{\mathrm{bill}}[h_+, h_-] + J_+ \cdot R[h_+] - J_- \cdot R[h_-]\}\,. \tag{1}$$

Here h_+ and h_- are the two branches of the closed history, $A[h]$ is the phase/action part of the history, A_{bill} is the record-action or billing cost associated with non-unitary record mismatch, and $R[h]$ is the record observable to which an apparatus couples. The response observable is obtained by differentiating Z with respect to the source.

For example, a one-point response has the form

$$\langle R(t)\rangle = \frac{1}{\mathrm{i}} \frac{\delta \log Z}{\delta J_+(t)}\bigg|_{J_+=J_-=0}, \tag{2}$$

while a connected two-point response is

$$G_R(t,t') = \frac{\delta^2 \log Z}{\delta J_+(t)\,\delta J_-(t')}\bigg|_{J_+=J_-=0} \quad \text{with the retarded branch prescription.} \tag{3}$$

The exact sign convention is not the point here. The point is that measured quantities are derivatives of the apparatus-coupled response functional, not raw entries in a finite catalogue.

Principle 1 (Response-promotion rule)**.** *A finite count C may be promoted to a physical observable O only if a specified apparatus coupling $J \cdot R$ and response functional $Z[J_+, J_-]$ give $O = C$ or a derived function of C. Without that map, the count remains a record fact, a candidate, or a useful approximation, but not a prediction.*

The purpose of this principle is not to make the framework harder to falsify. It does the opposite. It says exactly where falsification must occur. If a sector predicts a count but the measured response reads a different object, the claim is demoted. If the correct response is computed and disagrees with data, the branch fails.

3 Toy calculation: occupancy is not current

Let a monitor have N equally likely labels, one of which is selected. Then

$$p = \frac{1}{N}.$$

There are at least two inequivalent observables:

(a) the instantaneous occupancy $X \in \{0, 1\}$, with

$$\langle X \rangle = p, \qquad \mathrm{Var}(X) = p(1 - p);$$

(b) the monitored firing current $j(t) = \sum_n \delta(t - t_n)$, with Poisson low-frequency cumulant

$$S_j(0) = \lim_{T\to\infty} \frac{1}{T} \mathrm{Var}\left(\int_0^T j(t)\, \mathrm{d}t \right) = \Gamma p,$$

where Γ is the total attempt rate.

The same label probability p appears, but the readout differs. Occupancy contains $p(1 - p)$ — the variance of a Bernoulli trial — while the zero-frequency current noise contains p itself, because the accumulated count of a Poisson process has variance equal to its mean. A detector that measures a low-frequency current residue therefore reads a different object from a snapshot occupancy measurement. The distinction between snapshot statistics and continuously monitored currents is standard in quantum measurement theory [4, 40]; the point here is only that a finite model must say *which* of the two its count is promoted to.

In the finite-QEC substrate the bare service alphabet is

$$\mathrm{Sym}^2(16) + 1 = 136 + 1 = 137, \tag{4}$$

so the bare service probability is

$$\alpha_0 = \frac{1}{137}. \tag{5}$$

Equation (4) is a record fact. The response statement is stronger: low-energy charge must bill the monitored endpoint current, not the instantaneous occupancy. The response rule therefore selects the current residue $p = 1/137$, not $p(1 - p)$. This is the smallest example of why a record count and a physical observable are not the same kind of object.

4 The operator core: recorded insertions dephase

The preceding sections treat the record/response split as a classification. This section states the operator theorem that *derives* it. Every step can be checked on 2×2 and 4×4 matrices, and that is the point: the discipline does not rest on a deep conjecture but on the basic structure of monitored quantum dynamics [4, 28, 40].

The setting is a system with a distinguished *record-label* basis $\{|a\rangle\}$ — the pointer basis selected by the monitoring environment [41, 42] — and ancilla record states $|R_a\rangle$ written by service events. Perfect records are orthogonal, $\langle R_a|R_b\rangle = \delta_{ab}$; an imperfect record of a binary label has overlap $\varepsilon = \langle R_0|R_1\rangle$.

Proposition 1 (Dephased insertions)**.**

(i) ***No retarded component.*** *If A, B, and ρ are all diagonal in the record-label basis, then* $\mathrm{Tr}(\rho\,[A,B]) = 0$ *identically. A recorded counter — an observable built from label-diagonal insertions on a label-diagonal (recorded) state — has exactly zero retarded response component.*

(ii) ***Classical factorization.*** *For N independent monitored channels, each undergoing an amplitude-$\sqrt{p}$ transition that writes a perfect record, the N-fold coincidence expectation computed from the full entangled state equals p^N exactly, with Bernoulli higher moments: no interference correction survives the records.*

(iii) ***Linear response suppression.*** *Let a probe couple to the coherence between record labels (an anti-diagonal operator), with label-diagonal evolution before and after a record of overlap ε. Then the retarded kernel obeys* $\chi_R(\varepsilon) = \varepsilon\,\chi_R(1)$ *exactly: finite in the coherent limit, identically zero at a perfect record.*

(iv) ***Dressing-blindness.*** *Any unitary applied to the system* after *the record is written leaves the recorded count unchanged (the count is a property of the already-written ancilla) and cannot resurrect the dead channel ($\chi_R(0)$ remains zero), while the same unitary shifts the coherent-channel response kernel at order one.*

Part (i) is a one-line proof: diagonal matrices commute, so every term of a commutator kernel through the recorded channel vanishes identically. The depth is not in the algebra but in the premise: monitoring is precisely the physical process that makes insertions and states diagonal in the record basis — that is what "a record was written" means.

Parts (ii)–(iv) are worth displaying as explicit models, because they are small enough to be a homework exercise and sharp enough to carry the whole discipline. For (ii), each monitored channel is the isometry

$$|0\rangle_{\mathrm{sys}}|0\rangle_{\mathrm{anc}} \;\longmapsto\; \sqrt{1-p}\,|0\rangle|R_0\rangle + \sqrt{p}\,|1\rangle|R_1\rangle.$$

With $p = 0.13$ and four channels (a 256-dimensional entangled state), the four-fold coincidence expectation evaluates to $p^4 = 2.8561 \times 10^{-4}$ at machine precision. For (iii), take a qubit in a generic superposition, phase (label-diagonal) evolution before and after a record of overlap ε, and σ_x insertions (pure cross-label probes). At generic phases the computed kernel is $\chi_R = (0,\, 0.154,\, 0.309,\, 0.463,\, 0.617)$ at $\varepsilon = (0,\, 0.25,\, 0.5,\, 0.75,\, 1)$: finite when coherent, exactly linear, dead at a perfect record. The linearity is structural, not numerical: with diagonal post-record evolution and anti-diagonal probes, every term of the correlator crosses the record exactly once, so it carries exactly one factor $\langle R_0|R_1\rangle = \varepsilon$, and no ε-independent term exists. For (iv), applying a generic unitary to the system after the record shifts that same response kernel by 1.26 while the recorded count moves by less than 10^{-16}, and the dead channel stays exactly dead.

One honest scope restriction: what dies at $\varepsilon = 0$ is the response *through the recorded label coherence*. Dynamics after the record can still respond in channels of its own that the record does not monitor. That is not a loophole; it is the content of the rule: a register suppresses response exactly in the channel it records, and nowhere else.

> A recorded event count is a diagonal Born weight: bare, classical in its higher moments, and invariant under everything that happens after the record. A response kernel lives in the commutator sector: it vanishes through a recorded channel, and it is the only object that radiative dressing can touch.

“Bare versus dressed” is therefore not a per-formula convention. It is the operator distinction between counters and kernels. In the QED chain of Section 5, the bare 1/137 is a counter-side object (the per-event service bill) and the measured $\alpha(0)$ is a kernel-side object (a retarded current residue); the two coexist without contradiction, and the dressing corrections belong exclusively to the second. Section 5 uses the dichotomy in one further place: a coincidence counter buried in the middle of a long dimensional chain must bill bare, which turns a two-branch convention ambiguity into a single falsifiable number.

5 QED example: from 137 to the dressed charge

The fine-structure constant is a sharp test because QED is measured with extraordinary precision [36]. A model that explains only that α^{-1} is “near 137” is not doing precision physics. The response layer separates the electromagnetic chain into four parts:

$$\boxed{\text{bare current residue} \to \text{finite Wilson-endpoint contact} \to \text{retarded running} \to \alpha(0), \alpha(M_Z).} \tag{6}$$

5.1 Bare current residue

The bare endpoint-current response gives

$$\alpha_0^{-1} = 137. \tag{7}$$

This is not claimed as the measured low-energy fine-structure constant. It is the bare monitored-current residue of the service alphabet.

5.2 Finite Wilson-endpoint contact

A physical charged endpoint is Gauss/Wilson dressed: it is not a naked label without its gauge field. The finite endpoint contact is therefore not a free constant but a local contact term associated with the source and detector endpoints. In the current substrate ledger, the contact count is

$$N_{\text{contact}} = 2\sum_f Q_f^2 - 1. \tag{8}$$

For the three-generation Standard-Model charge content,

$$\sum_f Q_f^2 = 16, \qquad N_{\text{contact}} = 31. \tag{9}$$

The subtraction in (8) removes the connected endpoint identity mode. The resulting one-contact approximation is the first term of an expansion in $\alpha_0/2\pi$,

$$\alpha^{-1}(0) \simeq \alpha_0^{-1} + c_1 \frac{\alpha_0}{2\pi} = 137 + \frac{31}{2\pi \cdot 137} = 137.036013162, \tag{10}$$

about 103 parts per billion high in α^{-1} relative to the measured low-energy value. This is already a stringent check: the contact is not allowed to spoil Ward–Takahashi transversality [35, 37], and the contact shifts the Thomson matching, not the asymptotic running kernel.

5.3 Second endpoint vertex

The next response term is a connected second Wilson-endpoint vertex. The current calculation identifies the dimensionless directional-projector excess

$$K_2 = 1 + \frac{1}{2}\left\langle \sum_{\mu=1}^{4} p_\mu^2 - \frac{1}{4} \right\rangle_{\text{BZ}}, \qquad p_\mu = \frac{\hat{k}_\mu^2}{\hat{k}^2}, \quad \hat{k}_\mu = 2\sin(k_\mu/2), \tag{11}$$

which evaluates to

$$K_2 = 1.065133299. \tag{12}$$

Including this term gives

$$\alpha^{-1}(0) = 137.035999106904. \tag{13}$$

Equation (13) is not presented as a completed derivation of all QED. It is a response-layer result: the bare count is promoted through a monitored-current residue and finite endpoint contacts. Full precision QED still includes higher loops, detector transfer, finite-density media, and hadronic vacuum polarization.

Three remarks sharpen the status of (13). First, the second-order coefficient is derived, not fitted: K_2 fixes $c_2 \simeq -10.41$ in the $\alpha_0/2\pi$ expansion, whereas the value that would best match experiment is -10.43 — the derived and best-fit numbers are close but *not* equal, which is the signature of an expansion rather than of parameter absorption. Second, the operator-map clauses behind (11) (compact one-link register, record–site addressing, cumulant order) have now been reconstructed from the record calculus itself, and the kernel is provably *stencil-invariant*: every single-harmonic lattice weight yields the same K_2 (an arcsine-law universality of the uniform Brillouin measure), while a genuinely different discretization class (a Symanzik-type multi-harmonic weight) displaces α^{-1} by about 0.7 ppb and is thereby a named, excludable ambiguity rather than a hidden one. Third, honesty about the experimental side: (13) sits +0.17 ppb above the 2018 CODATA recommendation and -0.51 ppb below the 2022 one [36]; the spread is dominated by the known tension between the rubidium and caesium atomic-recoil determinations, which is exactly where this branch will eventually be confirmed or killed.

5.4 Running to M_Z

Once $\alpha(0)$ is fixed, standard vacuum-polarization running takes the coupling to the Z-pole:

$$\alpha^{-1}(M_Z) \simeq \alpha^{-1}(0)(1 - \Delta\alpha_{\rm lep} - \Delta\alpha^{(5)}_{\rm had} - \Delta\alpha_t) \simeq 128.94\text{–}128.95. \tag{14}$$

The leptonic part is perturbative QED; the hadronic part is an R-ratio/QCD input in the present calculation [7, 20]. Thus the Z-pole value is a consistency node, not an independent framework input.

5.5 Counters are dressing-blind: an armed test of Newton's constant

The Proposition 1 dichotomy also settles a convention question that had been worth about one part in 10^3 on a headline prediction: when a chain of substrate factors contains powers of α, does each power take the bare value 1/137 or the dressed value 1/137.036? The answer is structural, not aesthetic. In the framework's Planck-mass chain the α^4 factor is a four-fold recorded coincidence — a counter — and by Proposition 1 a counter bills the bare diagonal Born weight with zero admixture of the dressed kernel value. Every α power in the chain is therefore bare, the two-branch ambiguity collapses, and the chain becomes a single prediction of Newton's constant from the proton mass:

$$G_{\rm pred} = 6.67218 \times 10^{-11}\ \mathrm{m}^3\,\mathrm{kg}^{-1}\,\mathrm{s}^{-2}, \tag{15}$$

which is -0.032% from the CODATA value — 14 times the experimental uncertainty in G, yet -0.6σ of the chain's own measured error band, which is dominated by one structural relation rather than by the inputs. This is the discipline working in both directions at once: the operator theorem removes a soft convention layer, and what remains is a sharp, live internal test — if the remaining relation error is proven small, the residual becomes a kill, not a comfort.

Table 1: QED response-status ledger. The point is not that every QED quantity is derived, but that each claim is assigned to the correct layer.

Claim	Status
Bare 1/137 is a monitored-current response	strong conditional result
Finite Wilson-endpoint contact 31	in-layer theorem / local contact rule
Second endpoint vertex K_2	operator-map clauses derived; stencil-invariant; sub-ppb agreement
Counter/kernel split (bare vs dressed)	operator theorem (Proposition 1)
Full precision QED phenomenology	not claimed
$\alpha(M_Z)$ from $\alpha(0)$	standard running consistency check

6 Black-hole example: count versus thermal response

The black-hole sector gives the cleanest example of a useful count that is not itself the measured observable. A finite horizon service ledger gives a candidate source-rate coefficient

$$\Gamma_0 = \frac{10}{27}\,\alpha_0\,\Lambda, \tag{16}$$

read as ten of the twenty-seven Moore-neighbourhood service slots of a horizon cell (the nine outward face slots plus one latch), with Λ the substrate rate scale. Matched through the response chain below, it reproduces the Stefan–Hawking scalar power to $P/P_{\mathrm{SB}} = 0.997$. In the current canon this is a *conditional transfer theorem* — it holds if horizon severing is closed-cell Landauer erasure over every nearest contact, a premise that is stated, audited, and revocable — neither a naked numerical coincidence nor a completed derivation. Either way, the count alone is not the observable.

The physical flux is a response. A local horizon state satisfying the KMS condition has the thermal detailed-balance relation

$$G^+(-\omega) = e^{-\beta\omega} G^+(\omega), \tag{17}$$

where $\beta = 1/T_H$ and T_H is the Hawking temperature [1, 19, 24, 30]. The near-horizon Bogoliubov response then gives the Planck occupation number

$$n_\omega = \frac{1}{e^{\beta\omega} - 1}. \tag{18}$$

The exterior Schwarzschild geometry filters the spectrum through greybody factors $\Gamma_{s\ell}(\omega)$ [32], so the flux measured at infinity has the standard response form (upper sign for bosons, lower for fermions)

$$\frac{\mathrm{d}E}{\mathrm{d}t} = \sum_{s,\ell,m} \int_0^\infty \frac{\mathrm{d}\omega}{2\pi}\, \frac{\Gamma_{s\ell}(\omega)\,\omega}{e^{\beta\omega} \mp 1}. \tag{19}$$

In the finite-QEC account, the horizon count supplies the local service scale; the measured flux is supplied by the response built from KMS balance, Bogoliubov mixing, and greybody transfer [8, 13]. As a check of the transfer layer itself, the framework's spin-$\frac{1}{2}$ greybody pipeline reproduces Page's massless-fermion emission power to 0.02%, and its rotating extension recovers superradiant amplification only in the standard Kerr window. The distinction is essential. The count is not discarded; it is reclassified as the source scale entering a response calculation.

7 Other sectors: response frontiers rather than count frontiers

The same rule reorganizes several currently difficult sectors.

7.1 CMB and halo branch

A pressureless zero-mode reservoir may have the right broad shape to restore the CMB matter budget, but the CMB is not measured as a count. It is measured through a Boltzmann response and a likelihood:

$$\text{components} \to \text{acoustic evolution} \to C_\ell^{TT}, C_\ell^{TE}, C_\ell^{EE}, C_\ell^{\phi\phi} \to \mathcal{L}_{\text{CMB}}. \tag{20}$$

The correct test is therefore a full Boltzmann/likelihood pipeline, followed by nonlinear halo modelling and a non-double-counting rule between zero-mode dust and any late R4/MOND-like response [2, 10, 27].

7.2 Strong sector

The finite confinement programme has exact singlet selection and leading strong-coupling Wilson strings. But physical QCD numbers require a continuum response:

$$\langle W(R,T)\rangle \to V(R) \to \sigma \to T_c/\sqrt{\sigma},\ m_{\text{gap}}/\sqrt{\sigma}. \tag{21}$$

Thus the finite record geometry can demonstrate the correct confinement structure, while the physical string tension remains a weak-coupling scale-setting problem [3, 9, 23, 39].

7.3 Electroweak pole masses

Endpoint and billing maps can constrain the electroweak sector, but measured m_W, m_Z, and m_H are pole masses. A pole mass is a response object:

$$D^{-1}(p^2) = p^2 - m_0^2 - \Pi(p^2), \qquad D^{-1}(m_{\text{pole}}^2) = 0. \tag{22}$$

Therefore the record layer may specify a boundary condition or finite billing rule, but the pole requires running, matching, and self-energy corrections. This is not a retreat; it is the correct type of observable.

This sector now carries two worked instances of the discipline, both executed against published multi-loop Standard-Model parametrizations rather than in-house proxies. First, the weak mixing angle. The substrate's endpoint value $s^2 = 2/9$ is neither the on-shell value nor the bare tree value; locating it inside the standard Sirlin chain shows it is the partial-Δr point that absorbs 91.5% of the full pole shift $\Delta r = 0.036019$. The exposure it does *not* absorb, $+0.00305 \pm 0.00079$, then becomes a single derivation target, and the counter/kernel split of Section 4 supplies a candidate with no free numbers: the endpoint register is a matter-record register, so it bills the matter-channel exposure (the fermionic vacuum polarization and the full custodial fermion drag), while the gauge–Higgs sector's *self*-dressing writes no matter record and remains transfer. Evaluated from published two-loop electroweak results, that split predicts a missing exposure of $+0.00346$, i.e. $+0.5\sigma$ from the required value, and an equivalent $m_W = 80.363$ GeV — between the full Standard-Model transfer (80.355) and the measured 80.369 ± 0.013. The candidate and the full transfer differ by 7.4 MeV: indistinguishable today, decisive at FCC-ee precision. Second, the vacuum expectation value. The busy-projector family $\operatorname{Tr} P = 1 - 2^{-n}$, already fixed at physical depth six (63/64) by an acoustic billing theorem, recurs at logical depth four: a group-orbit enumeration over the sixteen logical codewords leaves a unique covariant projector with trace 15/16, and the resulting zero-parameter assembly

$$v = \frac{15}{16}\,\frac{\alpha_0^8 M_P}{\sqrt{\lambda_{\text{eff}}}} \tag{23}$$

(λ_{eff} the running quartic coupling at the top mass with its one-loop Coleman–Weinberg correction) lands at -0.12%, which is -0.2σ of the comparison's own error budget, while every rival covariant

Table 2: Response discipline as a falsification map.

Sector	Required response object	Failure mode
QED	endpoint current residue, finite contact, retarded running	Wrong residue, Ward violation, or failure of low-energy QED phenomenology.
Black holes	KMS/Bogoliubov response plus greybody transfer	Flux or spectrum disagreement once species and greybody factors are fixed.
CMB/halo	Boltzmann likelihood and nonlinear halo modelling	No fit to third peak, lensing, growth, or halo data without double counting.
Strong sector	Wilson-loop static potential and continuum scale setting	Finite confinement remains qualitative but cannot compute QCD ratios.
Electroweak	pole residues and fixed-scheme matching	Endpoint/billing maps fail to reproduce $W/Z/H$ pole masses; the current exposure candidate and the full SM transfer differ by 7.4 MeV in m_W — decisive at FCC-ee.
Newton's constant	dressing-blind coincidence counting (bare billing)	The bare-branch prediction sits at -0.032%; proving the remaining relation error smaller than that converts the residual into a kill.

exposure in the family is excluded at $\geq 8.9\sigma$. Both results are conditional in stated ways (an endpoint-register identification; a two-loop matching residue), but they illustrate the point of this section: the record layer supplies the boundary numbers 2/9 and 15/16; everything an experiment reads arrives through the response transfer.

8 Failure modes made sharper

The response discipline makes the framework more refutable. Table 2 lists representative examples.

The key methodological point is that a failure is not hidden by the response layer. It is exposed by it. A record count is allowed to become a prediction only after the response map is specified.

9 Discussion: why this is not a retreat

It may appear that the framework becomes more conditional when counts are reclassified as response-frontier problems. In one sense it does. But this is a gain in scientific discipline. A theory that can count many objects needs a rule that prevents over-promotion. The response-promotion rule supplies that rule.

The black-hole case illustrates the positive version. The count was close; the response gave the physical flux. The count was not thrown away, but it was placed at the correct layer. The QED case is sharper: 137 is not enough; the monitored-current residue, endpoint contact, second vertex, and running are needed before the number becomes a measured electromagnetic coupling.

The same rule also explains why the framework's recently killed dark-energy prediction is scientifically useful rather than embarrassing. The branch was recorded, frozen, confronted, and killed at the framework-internal tier by the pinned acoustic-scale response. It was not rescued by changing the denominator, adding hidden freedom, or moving the target after the fact [11]. Instead the registered form was frozen, the kill was recorded in a public outcome addendum, and two-sided *reopen* and *confirm* conditions were registered before the next-generation data exist: a specified tightening of the relevant BAO slope uncertainty with the optimum remaining on the predicted side, jointly with a persistent acoustic-scale tension. That is the response discipline working as intended — the same pre-registration machinery that armed the prediction also governs its afterlife.

10 Conclusion

The central claim of this paper is modest but strict:

records define what can be known; responses define what can be measured.

In a discrete record-based model, finite counts are indispensable. They define the substrate's grammar. But a physical prediction requires a further step: an apparatus coupling and a response map showing that the measured observable reads the count. That further step is now more than a taxonomy: on explicit finite models, the recorded count and the retarded response are provably different operator objects — one dressing-blind and classical in its moments, the other carrying all of the dressing (Proposition 1). The discipline is not an imported philosophy of science; it is a theorem about what monitored record dynamics lets an apparatus read.

This makes the finite-QEC substrate programme less permissive, not more. It turns attractive counts into tests. Some counts are promoted; some are demoted; some predictions are killed. That is the correct direction for a speculative framework that aims to become science rather than numerology.

Acknowledgement of status

This paper is not a proof of the finite-QEC substrate programme. It is a methodological layer for making the programme more refutable. The examples are included to show how the discipline operates in practice: QED is strong but not complete; black-hole flux is response-derived but still needs species-weight precision; CMB/halo and QCD scale setting remain explicit response frontiers; and the electroweak sector now carries its first two worked entries (the weak-mixing exposure split and the vacuum-expectation projector), each conditional in stated, named ways. Every numerical statement quoted here is backed by a self-checking script whose exit status is independent of the physics outcome; selected scripts are published in a public archive [16].

References

[1] Jacob D. Bekenstein. Black holes and entropy. *Physical Review D*, 7(8):2333–2346, 1973. doi: 10.1103/PhysRevD.7.2333.

[2] Diego Blas, Julien Lesgourgues, and Thomas Tram. The cosmic linear anisotropy solving system (CLASS). part ii: Approximation schemes. *Journal of Cosmology and Astroparticle Physics*, 2011(07):034, 2011. doi: 10.1088/1475-7516/2011/07/034.

[3] G. Boyd, J. Engels, F. Karsch, E. Laermann, C. Legeland, M. Lütgemeier, and B. Petersson. Thermodynamics of SU(3) lattice gauge theory. *Nuclear Physics B*, 469(3):419–444, 1996. doi: 10.1016/0550-3213(96)00170-8.

[4] Heinz-Peter Breuer and Francesco Petruccione. *The Theory of Open Quantum Systems*. Oxford University Press, 2002. doi: 10.1093/acprof:oso/9780199213900.001.0001.

[5] Esteban A. Calzetta and Bei-Lok B. Hu. *Nonequilibrium Quantum Field Theory*. Cambridge University Press, 2008. doi: 10.1017/CBO9780511535123.

[6] Giulio Chiribella, Giacomo Mauro D'Ariano, and Paolo Perinotti. Informational derivation of quantum theory. *Physical Review A*, 84:012311, 2011. doi: 10.1103/PhysRevA.84.012311.

[7] Michel Davier, Andreas Hoecker, Bogdan Malaescu, and Zhiqing Zhang. A new evaluation of the hadronic vacuum polarisation contributions to the muon anomalous magnetic moment and to $\alpha(m_z^2)$. *The European Physical Journal C*, 80:241, 2020. doi: 10.1140/epjc/s10052-020-7792-2.

[8] David Elliman. Going deeper into a black hole: The horizon as a quantum-error-correcting register surface. https://doi.org/10.5281/zenodo.21111941, 2026.

[9] David Elliman. Colour confinement as finite record geometry: Closed-cell triality, wilson strings, tensor-network entropy, the baryon y-junction, and finite-temperature deconfinement in a bond-bipyramid qec substrate. https://doi.org/10.5281/zenodo.21111292, 2026.

[10] David Elliman. Cosmology, dark energy, and inflation in the finite-QEC substrate. https://doi.org/10.5281/zenodo.21066087, 2026.

[11] David Elliman. A rational target for dynamical dark energy: $w_0 = -27/28$, $w_a = -1/28$. https://doi.org/10.5281/zenodo.21049001, 2026. Concept DOI; outcome addendum version published as https://doi.org/10.5281/zenodo.21128727.

[12] David Elliman. Foundations and methodology for a finite-QEC substrate: Code, crystallisation, ledgers, and audit protocol. https://doi.org/10.5281/zenodo.21111257, 2026.

[13] David Elliman. Gravity, horizons, and black holes in the finite-QEC substrate. https://doi.org/10.5281/zenodo.21111947, 2026.

[14] David Elliman. A finite-QEC substrate program for particle physics and cosmology: Current canon and audit methodology. https://doi.org/10.5281/zenodo.21111287, 2026.

[15] David Elliman. A finite record reconstruction of the standard model representation: Why the chiral anomaly-free spectrum is non-generic. https://doi.org/10.5281/zenodo.20998562, 2026.

[16] David Elliman. It-from-bit public executable scripts. https://github.com/dgedge/itfrombit, 2026. Public script archive for selected finite-QEC substrate calculations.

[17] Richard P. Feynman and F. L. Vernon. The theory of a general quantum system interacting with a linear dissipative system. *Annals of Physics*, 24:118–173, 1963. doi: 10.1016/0003-4916(63)90068-X.

[18] Lucien Hardy. Quantum theory from five reasonable axioms. arXiv:quant-ph/0101012, 2001.

[19] Stephen W. Hawking. Particle creation by black holes. *Communications in Mathematical Physics*, 43:199–220, 1975. doi: 10.1007/BF02345020.

[20] Fred Jegerlehner. *The Anomalous Magnetic Moment of the Muon*. Springer, 2017. doi: 10.1007/978-3-319-63577-4.

[21] Alex Kamenev. *Field Theory of Non-Equilibrium Systems.* Cambridge University Press, 2011. doi: 10.1017/CBO9781139003667.

[22] L. V. Keldysh. Diagram technique for nonequilibrium processes. *Soviet Physics JETP*, 20: 1018–1026, 1965. Original Russian version published in 1964.

[23] John B. Kogut. An introduction to lattice gauge theory and spin systems. *Reviews of Modern Physics*, 51(4):659–713, 1979. doi: 10.1103/RevModPhys.51.659.

[24] Ryogo Kubo. Statistical-mechanical theory of irreversible processes. i. general theory and simple applications to magnetic and conduction problems. *Journal of the Physical Society of Japan*, 12(6):570–586, 1957. doi: 10.1143/JPSJ.12.570.

[25] Ryogo Kubo. The fluctuation-dissipation theorem. *Reports on Progress in Physics*, 29(1): 255–284, 1966. doi: 10.1088/0034-4885/29/1/306.

[26] Rolf Landauer. Irreversibility and heat generation in the computing process. *IBM Journal of Research and Development*, 5(3):183–191, 1961. doi: 10.1147/rd.53.0183.

[27] Antony Lewis, Anthony Challinor, and Anthony Lasenby. Efficient computation of cosmic microwave background anisotropies in closed friedmann–robertson–walker models. *The Astrophysical Journal*, 538(2):473–476, 2000. doi: 10.1086/309179.

[28] Göran Lindblad. On the generators of quantum dynamical semigroups. *Communications in Mathematical Physics*, 48:119–130, 1976. doi: 10.1007/BF01608499.

[29] Umberto Marini Bettolo Marconi, Andrea Puglisi, Lamberto Rondoni, and Angelo Vulpiani. Fluctuation–dissipation: response theory in statistical physics. *Physics Reports*, 461(4–6): 111–195, 2008. doi: 10.1016/j.physrep.2008.02.002.

[30] Paul C. Martin and Julian Schwinger. Theory of many-particle systems. I. *Physical Review*, 115(6):1342–1373, 1959. doi: 10.1103/PhysRev.115.1342.

[31] Lluís Masanes and Markus P. Müller. A derivation of quantum theory from physical requirements. *New Journal of Physics*, 13:063001, 2011. doi: 10.1088/1367-2630/13/6/063001.

[32] Don N. Page. Particle emission rates from a black hole: Massless particles from an uncharged, nonrotating hole. *Physical Review D*, 13(2):198–206, 1976. doi: 10.1103/PhysRevD.13.198.

[33] Julian Schwinger. Brownian motion of a quantum oscillator. *Journal of Mathematical Physics*, 2(3):407–432, 1961. doi: 10.1063/1.1703727.

[34] Lukas M. Sieberer, Michael Buchhold, and Sebastian Diehl. Keldysh field theory for driven open quantum systems. *Reports on Progress in Physics*, 79(9):096001, 2016. doi: 10.1088/0034-4885/79/9/096001.

[35] Yasushi Takahashi. On the generalized ward identity. *Il Nuovo Cimento*, 6:371–375, 1957. doi: 10.1007/BF02832514.

[36] Eite Tiesinga, Peter J. Mohr, David B. Newell, and Barry N. Taylor. CODATA recommended values of the fundamental physical constants: 2022. *Reviews of Modern Physics*, 97(2): 025002, 2025. doi: 10.1103/RevModPhys.97.025002.

[37] John Clive Ward. An identity in quantum electrodynamics. *Physical Review*, 78(2):182, 1950. doi: 10.1103/PhysRev.78.182.

[38] John Archibald Wheeler. Information, physics, quantum: the search for links. In Wojciech H. Zurek, editor, *Complexity, Entropy and the Physics of Information*. Addison-Wesley, 1990.

[39] Kenneth G. Wilson. Confinement of quarks. *Physical Review D*, 10(8):2445–2459, 1974. doi: 10.1103/PhysRevD.10.2445.

[40] Howard M. Wiseman and Gerard J. Milburn. *Quantum Measurement and Control*. Cambridge University Press, 2010. doi: 10.1017/CBO9780511813948.

[41] Wojciech H. Zurek. Pointer basis of quantum apparatus: Into what mixture does the wave packet collapse? *Physical Review D*, 24(6):1516–1525, 1981. doi: 10.1103/PhysRevD.24.1516.

[42] Wojciech H. Zurek. Decoherence, einselection, and the quantum origins of the classical. *Reviews of Modern Physics*, 75(3):715–775, 2003. doi: 10.1103/RevModPhys.75.715.

[43] Wojciech H. Zurek. Quantum Darwinism. *Nature Physics*, 5:181–188, 2009. doi: 10.1038/nphys1202.