Finite-Information QCD:
A Pre-Registered Fingerprint Protocol at a Derived Lattice Spacing

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Abstract

In the finite-QEC substrate programme the lattice spacing is not a regulator: it is a derived physical constant, $a_0 = 0.59494\,\text{fm}$ (equivalently $\hbar c/a_0 = 331.7$ MeV), with no continuum limit to take. Deviations from continuum-extrapolated QCD at this spacing are therefore *predictions*, not artifacts — but such a claim invites unlimited after-the-fact fitting unless the deviation list is frozen first. This document freezes it. We register: (i) the closed, four-item fingerprint list (an orientation-averaged $\ell = 4$ potential scalar; the three-quark junction geometry; glueball mass ratios at a_0; the roughening/Lüscher crossover), each with estimator, comparator, and kill rule; (ii) the paired-lattice differential protocol that separates geometry fingerprints from generic finite-spacing effects; (iii) the gate results that scoped the list — the isotropy gate (domain averaging kills all orientation-vector signals; Hughes–Drever-class bounds are cleared by construction, with the surviving sensitivity $c \lesssim 4 \times 10^{-18}$ registered as a standing falsifier) and the dispersion/umklapp audit (free kinematics is record-grade exact; the umklapp channel dies four enumerated ways; the free-kinematics fingerprint class is *empty* and is retired); and (iv) a two-stage freeze discipline: this document fixes the hypothesis space and decision rules before any production compute, and a versioned addendum will fix measured coefficients before the physical-point confrontation. Every outcome is informative: a null across all four fingerprints is a universality result that hardens the programme's QCD-reproduction claim, while the glueball clause gives the physical-point claim a genuine external kill.

1 The claim class and what is frozen

Standard lattice QCD treats the spacing a as a regulator and takes $a \to 0$; whatever depends on the lattice dies in that limit by universality. The finite-QEC substrate programme [1, 2] makes the opposite move: the substrate spacing is *derived* — $a_0 = 0.59494\,\text{fm}$ on the bare branch of the Λ^* chain, with no adjustable freedom — and physical QCD *is* the theory at that spacing. Consequently:

> *Deviations from continuum-extrapolated QCD at a_0 are predictions of the programme. "Lattice artifacts" become physics, at a spacing that is not a dial.*

A claim of this shape is methodologically dangerous: with enough post-hoc freedom, some "deviation" can always be found. The defence is pre-registration, in the same discipline as the programme's five standing pre-registered predictions [1, 3–6]: freeze the complete candidate list, the estimators, the comparators, and the kill rules *before* production compute; record the census of candidates already considered and retired; forbid additions after the timestamp (a new candidate requires a new pre-registration, and is marked as such).

Two-stage freeze. Stage A (this document): the hypothesis space and decision rules. Stage B (a versioned addendum to this record): the measured geometry coefficients from the paired differentials, frozen numerically — with uncertainties — *after* the instrument runs but *before* the physical-point evaluation they feed. Stage A kills scanning; Stage B kills tuning.

2 The derived spacing and its immediate scales

The registered numbers, all fixed by prior canon and none adjustable here:

substrate spacing	$a_0 = 0.59494\,\mathrm{fm}$ (bare branch, Λ^* chain)
link quantum	$\hbar c/a_0 = 0.33168\,\mathrm{GeV}$
zone ceiling	$\pi\hbar c/a_0 = 1.0420\,\mathrm{GeV}$
string tension at a_0	$\sigma a_0^2 \simeq 1.76$ (with $\sqrt{\sigma} = 440$ MeV): deep strong coupling
scaling-regime anchor	$\beta^* = 5.7694$, $\sigma a^2 \simeq 0.14$ ($a \simeq 0.17\,\mathrm{fm}$)

Cross-lane consistency, recorded because it was *found*, not arranged: the trans-Λ null-chain formalisation independently fixed $N = 3015$ service units for a 1 TeV quantum, and $1000/3015 = 0.33167\,\mathrm{GeV}$ agrees with $\hbar c/a_0$ to $< 0.1\%$ — the service count is the a_0 hop count. The K04 non-mobility pre-registration's drive number $R_{\mathrm{drive}} = a(2a_0)/c^2 \simeq 1.6 \times 10^{-42}$ [6] reproduces from the same a_0 to 0.7%. Three lanes, one spacing.

3 The gates that scoped the list

3.1 F0 — isotropy (executed)

A substrate with a fixed global orientation would put $\ell = 4$ anisotropy into atomic and nuclear levels at strengths excluded by Hughes–Drever-class clock comparisons [7]. The programme's crystallisation history produces *domains*: the measured Kibble–Zurek exponent $\mu = 0.22 \pm 0.03$ gives crystallites of scale $\xi \sim 1.5 \times 10^4\, a_0 \approx 9$ pm — sub-atomic. Lab observables average over $\sim 10^7$–10^{15} domains; the residual orientation-vector couplings are bounded by a Mössbauer-linewidth budget at $c < 3 \times 10^{-17}$ and a sidereal-modulation budget at $c < 4 \times 10^{-18}$. Consequences frozen here: (a) all orientation-*vector* fingerprints (sidereal signals, fixed-axis anisotropies) are *dead by construction* and excluded from the list; (b) surviving fingerprints are *orientation scalars* — domain-averaged quantities; (c) the record-grade protection is a *standing falsifier*: a confirmed laboratory sidereal signal above the 10^{-18} grade attributable to a fixed spatial frame would falsify the domain picture outright.

3.2 F5′ — dispersion protection and the umklapp census (executed)

The obvious objection — "a 1/ GeV lattice must show $O(1)$ dispersion at accelerator momenta, and umklapp momentum non-conservation at the zone scale" — dies in four enumerated ways:

1. free kinematics is *record-grade*: chain velocity is ℓ/τ independent of energy at any order; the isotropic Lorentz-violation coefficients are predicted identically zero against current headroom $|\zeta_1| < 3.2 \times 10^{-21}$ [8]; total-leg kinematics is subdivision-uniform (no reference to the substrate scale survives);

2. the chain auto-zone-folds: every elementary service event carries exactly the link quantum 0.33168 GeV, below the zone ceiling with margin exactly π — no elementary event can present a trans-zone momentum to the lattice;

3. direct lattice recoil is a *correctable error*: the vacuum is an actively corrected code state; a would-be reciprocal-vector recoil raises a syndrome and is serviced back, carrying no record weight. Momentum-conservation exactness *is* the code's error correction of lattice recoil;

4. the one physical remnant — momentum absorption by domain walls and pinned fossils — is bounded by the published K04 non-mobility pre-registration [6].

Binding output: the free-kinematics fingerprint class is *empty*. The former candidate F5 ("bound-state dispersion remnants") is **retired**; its admissible content is bound-state structure, already owned by F3/F4 below. The lattice scale can enter observables *only* through bound-state structure — exactly where QCD already has nonperturbative content.

4 The frozen fingerprint list

The list is **closed**: four fingerprints, two falsifiable-only registers. No additions after the timestamp of this record.

F1 — orientation-averaged $\ell = 4$ potential scalar

Definition. The rotationally invariant $\ell = 4$ content of the static potential at fixed r: the domain-averaged scalar $\bar{c}_4(r)$ built from on-axis vs body-diagonal $V(r)$ differences (the orientation-*vector* form is dead by F0 and demoted to instrument characterisation on the paired lattices). **Where.** Paired differential first; then a_0. **First-pass window (non-binding).** $O((a_0/r)^2) \times c_{\text{TCH}}$: tens of percent $\times c_{\text{TCH}}$ at $r \sim 1\,\text{fm}$ if $c_{\text{TCH}} = O(1)$; enters orientation-averaged spectroscopy at percent class. **Comparator.** Continuum QCD: zero after extrapolation; quarkonium fine structure (averaged). **Kill/confirm.** c_{TCH} consistent with zero ($< 2\sigma$) at both paired spacings $\Rightarrow$ F1 null. Nonzero at $\geq 3\sigma$ with the same sign at both spacings $\Rightarrow$ promoted to Stage B numeric freeze.

F2 — three-quark junction geometry

Definition. The Y-junction term in the baryonic potential: junction energy offset and junction-shape response (the Y vs Δ discrimination and the junction-point stiffness) on the TCH geometry vs cubic. **Where.** Paired differential (three-quark Wilson loops on the validated variational base). **First-pass window (non-binding).** Junction-term shift of a few percent of σL_Y. **Comparator.** Cubic-lattice three-quark studies [9]; baryon spectroscopy (weak). **Kill/confirm.** Junction energy and shape indistinguishable from the matched cubic run within errors $\Rightarrow$ null. A systematic TCH$-$cubic difference at $\geq 3\sigma$ $\Rightarrow$ promoted to Stage B.

F3 — glueball mass ratios at a_0

Definition. The ratios $m_{2^{++}}/m_{0^{++}}$ and $m_{0^{-+}}/m_{0^{++}}$ evaluated *at the physical spacing* (strong-coupling expansion cross-checked by Monte Carlo spot runs). **Where.** Physical point. **First-pass window (non-binding).** Several-percent shifts of the ratios relative to continuum-extrapolated values (the 0^{++} is the sensitive channel). **Comparator.** Continuum-extrapolated lattice values [10]; experimental glueball candidates when the experimental situation cleans up. **Kill/confirm**

— **note the asymmetry.** This clause can kill the *programme's physical-point claim*, not only the fingerprint: the framework's physical glueball masses *are* the a_0 values. If confirmed experimental values land on the continuum-extrapolated numbers and exclude the a_0-shifted ratios at $\geq 3\sigma$, the physical-point reframe is falsified. Conversely a confirmed shift toward the a_0 values is the programme's cleanest positive fingerprint. (No kill fires while the experimental identification of glueball states remains unsettled; the clause simply waits, frozen.)

F4 — roughening/Lüscher crossover

Definition. The scale and shape of the crossover between the rigid-string regime and the rough-string regime in the physical potential: the effective Lüscher coefficient $c_L(r)$ (continuum value $-\pi/12$ [11, 12]) as a function of r, and the torelon/width observables that locate roughening. **Where.** Both regimes. **First-pass window (non-binding).** The $-\pi/12r$ term modified at the 10–50% level below the roughening scale at coarse spacing. **Comparator.** Fine-lattice/cubic values; Cornell+Lüscher quarkonium fits. **Kill/confirm.** Crossover absent or at the matched-cubic location $\Rightarrow$ null. TCH-shifted at $\geq 3\sigma \Rightarrow$ promoted to Stage B, with the quarkonium-relevant r window stated.

Falsifiable-only registers (already public, cross-referenced)

- **LV/dispersion:** $\zeta_n = 0$ identically, against [8] bounds — any confirmed nonzero isotropic ζ falsifies the record-grade dispersion sector.
- **Fossil mobility:** the K04 non-mobility prediction [6] — a demonstrated mobile K04 component falsifies the pinning sector that the umklapp census leans on.

5 The paired-lattice differential protocol

Every in-simulation fingerprint is evaluated as a *difference*:

1. run the identical measurement protocol on the TCH/bond-bipyramid geometry and on cubic Wilson [13] at *matched physical scale* $a\sqrt{\sigma}$ (the campaign anchor $\beta^* = 5.7694$, $\sigma a^2 \simeq 0.14$, and one finer matched point);
2. identical estimator stacks (the validated variational static-potential base; the same GEVP conventions, fit windows, and error model on both geometries);
3. the fingerprint is the TCH$-$cubic difference; anything shared is generic finite-a and is *not* a fingerprint;
4. orientation observables are domain-averaged per F0 before any comparison;
5. **instrument precondition:** production fingerprint runs are licensed only after the pair-source-enriched instrument passes its validation gate (seed-magnitude reconciliation and linear-tail sign at campaign statistics). An unstable instrument re-gates the lane; it does not soften the rules.

6 Census, trials ledger, and outcome space

Census of candidates considered and disposed of before this freeze (the ledger that makes the closed list honest): the orientation-*vector* $\ell = 4$ anisotropy (demoted to instrument characterisation — F0); free-particle dispersion remnants and all umklapp signatures (class empty — F5′, four enumerated deaths); bound-state dispersion remnants as a standalone row (retired into F3/F4 — F5′). No other candidates were evaluated against data at any point; no magnitude was compared to any measurement in selecting this list.

Outcome space, declared:

- *All four null* at the achieved precision ⇒ a universality result: the TCH geometry reproduces cubic QCD at matched scale — recorded as *hardening* the programme's QCD-reproduction claim, and the physical-point story then rests entirely on the absolute (F3-class) clauses. This outcome is acceptable and would be published as such.
- *Any fingerprint promoted* ⇒ Stage B numeric freeze, then the physical-point confrontation with the frozen number.
- *F3's external clause fires against us* ⇒ the physical-point reframe is falsified; the paired-differential results remain valid lattice results.

Rigidity. No addition to the list after this record's timestamp; a new candidate requires a new pre-registration marked as post-hoc relative to this one. Stage B may only *narrow* windows to measured values; it may not add channels, change estimators, or alter kill thresholds. The trials ledger travels with every subsequent addendum.

7 Relation to the standing pre-registration series

This is the sixth registered instrument of the programme, and the first to register a *protocol* rather than a single number — the same freeze-before-look discipline applied to a deviation search: dark energy [3], the sterile-neutrino X-ray line [4], the primordial-tensor null [5], K04 fossil non-mobility [6], and Newton's constant [1]. As there, the point is not confidence but *legibility*: when the runs complete, it will be checkable that the questions were fixed before the answers existed.

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