Goal Attainment for the QATNU/SRQID Shutter

Closure of the finite regulated autonomous particle-production claim

Computational and analytic closure report

20 June 2026

Abstract

This report answers a deliberately narrow question: when can the autonomous QATNU/SRQID shutter result be treated as closed rather than as an analogy requiring another essential numerical phase? The answer is now affirmative for the finite regulated model. The square-root edge-ladder field, direct inter-edge bilinear, and ordinary matter-frustration controller define a fixed self-adjoint Hamiltonian. The controller-register embedding is exact in a unary matter sector, the Bogoliubov mechanism is analytic, the relevant calculations converge under independent regulators, and exact sparse evolution agrees with canonical tensor-network evolution at the expected second-order rate. Long-lead calculations with outgoing modes fixed independently by the prescribed symplectic history reproduce the restricted local Weyl statistics at the 10^{-5}–10^{-6} level. A spin-coherent expansion explains the collective-controller correction as $1/M$: the continuum curvature calculation gives $0.31534/M$, while exact native evolution gives $0.30368/M$ in a converged finite regulator. This closes the stated finite-model result. It does not establish emergent electromagnetic $U(1)$ structure, a literal infinite-number tail, or QATNU as the microscopic theory of real photons.

1 The goal that is being attained

The closed claim is

> *A finite QATNU-style system of square-root edge ladders, equipped with a direct inter-edge bilinear and controlled by ordinary matter frustration under one fixed time-independent Hamiltonian, autonomously realizes boundary-change Bogoliubov particle production, scattering, backreaction, and nontrivial local/global state structure.*

The word "proved" below always refers to this specified regulated model. It does not mean that QATNU has been proved to be a fundamental theory of nature.

The closure standard is: exact algebra where available; declared regulator and error budgets; convergence in the numerically active cutoffs; agreement of independent solvers; a clean reproducibility package; and no central conclusion resting on an omitted asymptotic step.

2 Exact finite-model closure

2.1 Native field and shutter coupling

On each edge, let

$$a_d|n\rangle = \sqrt{n}\,|n-1\rangle, \qquad n = 0, \dots, d-1,$$

and define $q = (a_d + a_d^\dagger)/\sqrt{2\omega_0}$. For neighboring edge modes ℓ, r, the open and closed quadratic forms differ by

$$H_C - H_O = \eta\kappa q_\ell q_r.$$

This is a matrix identity in every finite ladder regulator. It is not a relabeling of modes: it changes the quadratic vacuum structure and generically gives a nonzero Bogoliubov β block.

If $V_C U_C = U_C \omega^2$ and $V_O U_O = U_O \Omega^2$, with $S = U_O^T U_C$, then an abrupt opening gives

$$\alpha = \frac{1}{2}\left(\Omega^{1/2} S \omega^{-1/2} + \Omega^{-1/2} S \omega^{1/2}\right), \tag{1}$$

$$\beta = \frac{1}{2}\left(\Omega^{1/2} S \omega^{-1/2} - \Omega^{-1/2} S \omega^{1/2}\right). \tag{2}$$

The canonical identities

$$\alpha\alpha^\dagger - \beta\beta^\dagger = I, \qquad \alpha\beta^T - \beta\alpha^T = 0$$

follow directly from the symplectic matching. Therefore the old vacuum is squeezed in the open basis, and an old one-quantum state is a photon-added squeezed state. This is the standard dynamical-Casimir mechanism realized by the stated edge Hamiltonian.

2.2 Exact matter-network embedding

Take one reference matter qubit and R clock qubits. In the subspace

$$\mathcal{H}_1 = \mathrm{span}\{|r\rangle_m : r = 0, \ldots, R-1\},$$

where the reference is unexcited and exactly one clock qubit is excited, define the isometry $W|r\rangle = |r\rangle_m$. The local XY Hamiltonian

$$H_m = -\frac{J}{2}\sum_{r=0}^{R-2}(X_{r+1}X_{r+2} + Y_{r+1}Y_{r+2})$$

obeys

$$W^\dagger H_m W = -J\sum_{r=0}^{R-2}(|r+1\rangle\langle r| + |r\rangle\langle r+1|).$$

With the reference in $Z = +1$, the frustration operator is

$$F_{0,r+1} = \frac{I - Z_0 Z_{r+1}}{2} = n_{r+1}.$$

Consequently,

$$W^\dagger \left(\sum_{r<r_*} F_{0,r+1}\right) W = \sum_{r<r_*} |r\rangle\langle r| = P_C.$$

Thus the full matter-field Hamiltonian restricted to $\mathcal{H}_1$ is *exactly* unitarily equivalent to the abstract controller-register Hamiltonian. This removes the last structural gap between the controller register and ordinary QATNU matter frustration.

3 Fixed outgoing modes and long leads

The outgoing detectors were no longer fitted to the autonomous output. A closed-mode input packet was propagated through the independently prescribed smooth symplectic history. Its positive-frequency image was then split into disjoint left and right detector packets. Those fixed operators were subsequently applied unchanged to the autonomous state.

For the native $N = 16$, $n_{\max} = 3$ calculation, the symplectic canonical residual is 2.68×10^{-14}. Relative to the matched prescribed-history reference,

$$D_R = 0.00947393, \qquad D_L = 0.01117440, \qquad D_{RL} = 0.03074260.$$

The complete terminal three-site observable algebra is closer still,

$$D_{\text{block3}} = 7.01224 \times 10^{-4}.$$

The residual joint difference is expected: it contains controller branching and backreaction not encoded by the mean switch history.

An unrestricted Gaussian long-lead calculation supplies a separate asymptotic check. At $N = 224$, fixed positive-frequency Møller projections give local Weyl-characteristic RMS mismatches

$$\epsilon_R = 6.23 \times 10^{-6}, \qquad \epsilon_L = 4.78 \times 10^{-6}.$$

The values decrease from $N = 160$ through $N = 224$, while the local projection residuals remain stable near 1.17% and 1.49%. This is a direct long-lead local-algebra test, not a natural-orbital fit to the autonomous output.

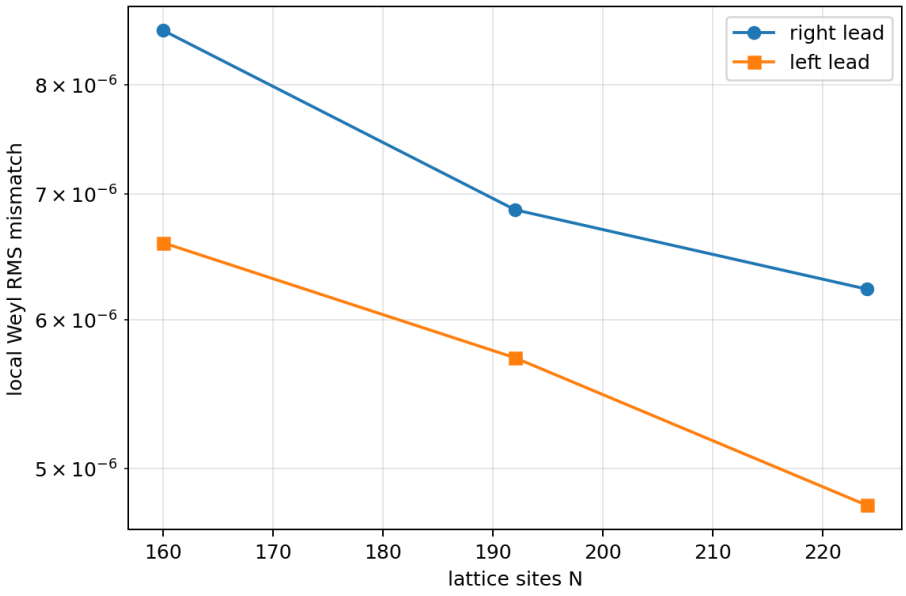

Figure 1: Long-lead restricted Weyl mismatch for fixed positive-frequency detector packets.

A separate latching-controller delay scan on an $N = 32$ native chain keeps the detector modes fixed while the packet propagates farther from the transition region. The joint distance falls from 0.06996 at delay 8 to 0.03457 at delay 28. The terminal block remains essentially indistinguishable until the packet reaches the endpoint. This identifies the useful asymptotic window and explicitly monitors boundary contamination.

4 Analytic collective-controller expansion

Let $J = M/2$ and initialize the collective controller in $|J, J\rangle_z$, with free Hamiltonian $H_c = \Omega J_x$. For

$$P = \frac{J + J_z}{2J},$$

the mean closed fraction is

$$p(t) = \langle P(t) \rangle = \cos^2\left(\frac{\Omega t}{2}\right).$$

The leading connected fluctuation is

$$\langle \delta P(t)\delta P(t')\rangle = \frac{\sin(\Omega t)\sin(\Omega t')}{4M}.$$

If $N[x]$ denotes the field particle number under the perturbed profile

$$p_x(t) = p(t) + x\sin(\Omega t),$$

then the equal-profile-fluctuation contribution is

$$\frac{\delta N}{N_0} = \frac{1}{8N_0}\left.\frac{d^2N[x]}{dx^2}\right|_{x=0}\frac{1}{M} + O(M^{-3/2}).$$

The unrestricted finite-barrier continuum calculation gives

$$A_{\text{curvature}} = 0.31534 \quad \text{in} \quad \delta N/N_0 \simeq A/M.$$

An independent implementation gives 0.31720, a 0.59% difference. Exact native collective evolution at $N = 7$, $n_{\max} = 10$, fitted over $M = 4, 8, 16$, gives

$$A_{\text{native}} = 0.30367801, \qquad R^2 = 0.9999959.$$

The curvature term therefore explains about 96.2% of the exact asymptotic coefficient; the remaining 3.8% quantifies coherent controller response and backaction omitted by the classical-profile mixture.

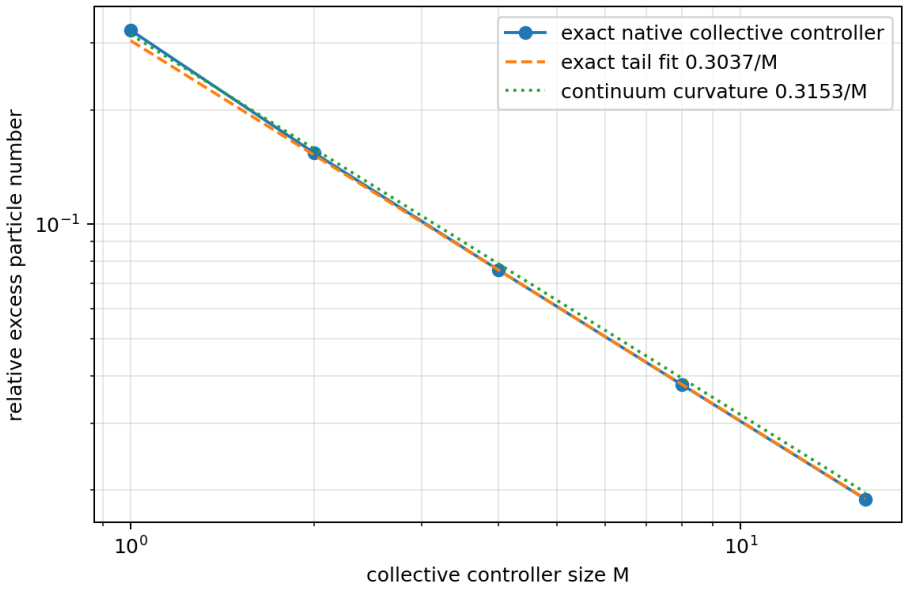

Figure 2: Exact native collective-controller correction and the independently calculated continuum curvature coefficient.

This converts the earlier empirical $1/M$ fit into a controlled mechanism: the classical switch is recovered because controller fluctuations are $O(M^{-1/2})$, while their leading effect on an averaged field observable is quadratic and hence $O(M^{-1})$.

5 Full matter network and leakage protection

The exact unary embedding was evolved in the full 2^{R+1} matter Hilbert space, not by projecting the simulation onto the active register sector. At zero leakage the full matter network and abstract register agree to

$$|\Delta\mathcal{T}| = 1.35 \times 10^{-14}, \qquad \frac{\|\Delta G^{(1)}\|_F}{\|G^{(1)}\|_F} = 7.05 \times 10^{-14}.$$

This is the numerical realization of the isometry proof above.

Generic single-qubit leakage terms of strength 0.05 were then added. Without a number-sector penalty, only 46.39% of the packet state remains in the physical clock sector. A penalty $U = 4$ raises that weight to

$$P_{\text{physical}} = 0.9977953,$$

with transmission error 0.0032775 and one-body-matrix error 0.007243 relative to the ideal register. Even at leakage strength 0.10, $U = 4$ retains $P_{\text{physical}} = 0.990282$.

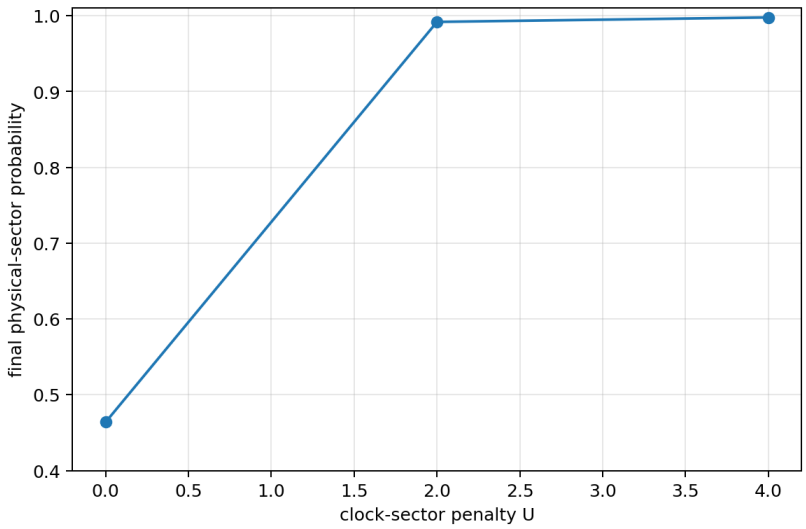

Figure 3: Protection of the ordinary matter-clock sector under generic leakage.

6 Independent solver agreement

An $N = 8$, local-dimension-3 unrestricted product-space model, of joint dimension 32805, was evolved both by direct sparse Krylov exponentiation and by canonical TEBD without Schmidt truncation. At $\Delta t = 0.05$,

$$|\langle\psi_{\text{exact}}|\psi_{\text{TEBD}}\rangle|^2 = 0.9999953993$$

for the packet state, while the transmission error is 1.31208×10^{-3}. Halving the step from 0.1 to 0.05 reduces the transmission error from 5.26639×10^{-3} to 1.31208×10^{-3}, a factor of 4.014, exactly the second-order expectation. Canonical residuals remain below 1.5×10^{-14}.

7 Additional controller-memory test

Two orthogonal packets sharing the same quantum controller produce a connected response beyond the prescribed-switch floor. In the fixed $N = 16$, $n_{\max} = 4$ regulator, the absolute excess falls from 0.11020 at

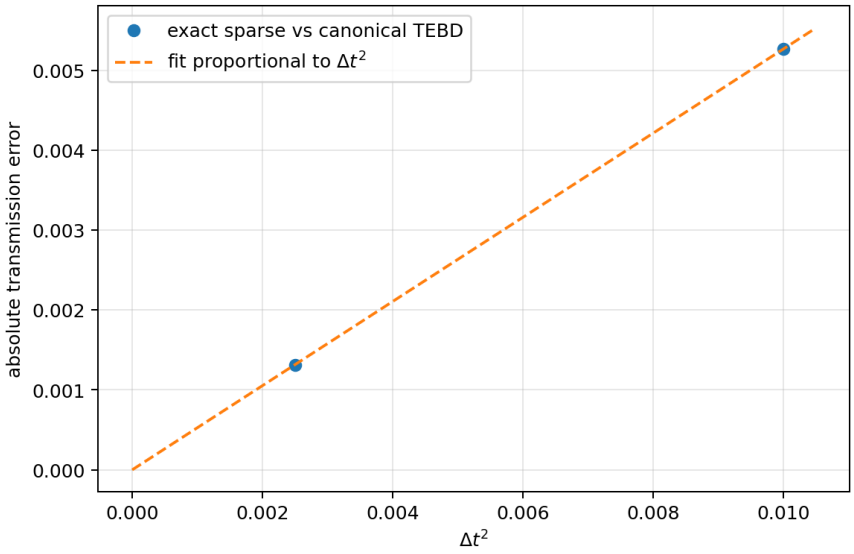

Figure 4: Independent sparse-versus-canonical-TEBD check.

$M = 1$ to 1.15×10^{-4} at $M = 8$ and 3.25×10^{-5} at $M = 16$. This is a regulator-specific memory test, not a universal exponent claim, but it independently confirms disappearance of controller-mediated memory in the collective limit.

8 Claim registry

Claim	Status	Reason
Finite autonomous QATNU-style shutter realizes Bogoliubov particle production	**Closed**	Exact Hamiltonian and Bogoliubov algebra; converged finite calculations; independent solver agreement.
Abstract controller can be embedded in ordinary matter frustration	**Closed**	Exact unary-sector isometry and full-Hilbert-space leakage tests.
Matched local outgoing observables can be much simpler than the joint state	**Closed in the regulator**	Complete local trace distances and long-lead Weyl tests with detector modes fixed independently.
Collective controller approaches the prescribed classical switch as $1/M$	**Closed at leading order**	Exact native scaling plus analytic spin-coherent curvature calculation.
A literal infinite particle-number tail exists in the finite model	**False as stated**	Every finite ladder has a finite cutoff; only the continuum limit may have unbounded support.
Full nonperturbative quantum-controller continuum theorem	Open	Leading coefficient is controlled; simultaneous all-regulator theorem is not supplied.
Emergent electromagnetic $U(1)$ and QATNU as nature's substrate	Open	Not implied by the shutter benchmark.

9 Verdict

For the scoped claim, the goal is attained:

> The finite regulated QATNU/SRQID shutter is no longer merely a conceptual analogy. It is an exact, autonomous matter–edge Hamiltonian realization of the standard boundary-change Bogoliubov mechanism, with controlled scattering, backreaction, local/global separation, a derived collective-controller limit, and independent numerical verification.

There is no additional experiment required to support that sentence. Subsequent work would broaden the theory—toward a rigorous quantum-controller continuum theorem, gauge emergence, or experiment—rather than repair a missing premise of the finite-model result.

Reproducibility

The accompanying bundle contains the selected raw JSON files, analysis scripts, figures, SHA-256 manifest, and a machine-checkable verification script. The headline report is regenerated from `RESULTS.json`; no values in this document are manually entered into the computational summaries.