1. Selection and decision

Measurable Realization and Published-Data Audit

CANDIDATE REALIZATION; DATASET-SCOPED AUDIT; PHYSICAL PROMOTION 0

Decision

Select a classical, nonlinear U(1) rotor-matter circuit emulator as the first measurable UD realization candidate. Start at rank one. This is a development choice based on access to classical quadratures and programmable nonlinear interactions, not a claim that a full UD apparatus already exists.

Published anchor

Riechert et al., Physical Review B 105, 205141 (2022), demonstrated five matter sites and four oscillator links using nonlinear LC circuits and three-wave mixing. Its published data and code provide the closest audited component benchmark. The paper reports local Gauss-law measurements, spectra and driven transport. Read the body and appendices, not just the abstract [1-3].

Why not the other platforms first?

Cold-atom experiments supply real gauge-simulator evidence, but the audited experiments use different quantum-link state spaces and readouts. Population measurements cannot be silently identified with the complex classical UD state. Passive linear circuits do not implement the nonlinear matter-link or plaquette interactions. These are reasons for this scoped selection, not a comprehensive ranking of all hardware.

Critical mismatch

The published circuit uses an unconstrained complex link oscillator b. Writing b=sqrt(I) exp(i theta) makes the hopping amplitude depend on link action I. UD instead requires U=exp(i theta) with independent signed electric E, plus an E-squared energy and diamond holonomies. Fixing the oscillator amplitude while claiming its action remains a freely dynamical electric variable is not an exact mapping. No such identification is admitted.

Scope

This audit concerns the finite classical Hamiltonian and its measurement contract. It supplies no evidence for coupling unification, proton decay or monopoles, and no Standard Model or continuum correspondence. Experimental data can test a declared physical realization; they do not prove the mathematical theorem. Independent review and physical validation remain outstanding.

2. What the selected apparatus must represent

Carrier and state

The full rank-one target has 15 nodes, 28 oriented links and 18 diamonds, not a K4 graph with only four oscillator sites. Record theta_e and signed E_e for all 28 links, and two complex matter fields at each of 15 nodes. Before norm constraints this is 116 real state coordinates. This coordinate count is not an independent sensor-count or hardware-cost theorem.

Hamiltonian target

With D_U[i,j]=b_e U_e and h_U=i(D_U^dagger-D_U), retain the frozen Hamiltonian H=(a/2) sum E_e^2 + kappa sum_d(1-Re W_d) + n_q q^dagger h_U q + n_w w^dagger h_U w + mu(n_q+n_w). The normalized matter fields have opposite symplectic signs and their actual positive norm weights. A valid circuit/controller map must reproduce those brackets as well as this energy.

Implementation candidate, not a completed design

Use phase-bearing rotor variables with signed electric integrators, IQ matter channels, nonlinear matter-link mixing and four-link diamond feedback. An analog or hybrid controller may be investigated. Its latency, gain, saturation, noise and filtering enter the actual defect budget; software that integrates the target equations is only a numerical emulator until apparatus correspondence is calibrated. No circuit schematic, component procurement list or realizability theorem is supplied here.

Measurable preparation

Recover the 27 real invariant scalars in GPC: alpha=S^dagger S, gamma=|S^dagger Z|^2, total electric square norm, 14 full cycle traces and 10 negative-cycle active moments. Use s=sqrt(alpha), u=sqrt(gamma/alpha). At rank one the active moments are algebraically redundant with alpha and the corresponding real cycle traces; retain the frozen 27-channel interface conservatively. This does not establish a minimal measurement scheme.

Separate dynamics admission

In addition to the preparation score, obtain actual orbit-relative energy, coefficient/error bounds, positive norm floors and source/defect histories. The SDW budget requires every-prefix work, parameter-gradient variation and absolute/positive norm variation. Exact zero-Gauss admission requires initial G=0 and vanishing covariant source; small observed drift is not a repair. Rank-one tests cannot establish unused-color claims at higher rank.

3. Published data: access and coverage

A / Riechert circuit: selected primary benchmark

heiDATA DOI 10.11588/DATA/6MEKHI, released 3 February 2022, version 1.0: metadata lists 71 unrestricted files, including compressed acquisitions, KiCad files, acquisition code and two notebooks. Data license CC BY 4.0; code BSD 2-Clause. The landing page and ordinary dataset endpoint returned HTTP 500 during this audit; the public metadata export and individual text-file endpoints worked. The README links to tychon/U1CircuitsData. Its audited Git commit is 265b6671dde799d7c73f32247fa3ee93ae70e0f2 [2-3].

A / Content inspected

Read the README, acquisition documentation, Gauss extraction code and relevant notebook cells without executing imported scripts. Downloaded and parsed one complete ten-channel compressed acquisition. Its 30,941,478 bytes and MD5 81771941562f83818f3d905bd6f9e9e2 match heiDATA file 6385, DOI suffix 4PV8ZU. This is a content audit of one file, not a replay of all figures or all 71 files.

B / Yang 71-site experiment

Nature 587, 392-396 (2020); Harvard Dataverse DOI 10.7910/DVN/3RXD5F, version 1.1: 13 unrestricted files, CC0. Inventory includes Codes.rar and 12 figure tables. Read the full Fig.4.tab response, not the RAR or all tables. It has five numeric rows at 0, 30, 60, 90 and 120 ms, two population estimates and their standard deviations. The paper uses correlated atom occupations to assess local gauge-invariant states [4-5].

C / Mil atomic-mixture building block

Science 367, 1128-1130 (2020); Dryad DOI 10.5061/dryad.8gtht76k2 lists seven CSV files, about 4.52 KB. Read three file contents: Fig.2 lithium (9 rows), Fig.2 sodium (20 rows), Fig.3 (20 rows). Each has a time/pulse-length column, mean population or polarization, and error on mean. Remaining four CSV contents were not inspected; the landing-page extraction did not expose license terms, so no reuse-license claim is made here [6].

D / Excluded from experimental evidence

The 2025 article Large-scale 2+1D U(1) gauge theory with dynamical matter in a cold-atom quantum simulator is a proposal with perturbative and iMPS numerical benchmarks, not a newly acquired experimental dataset. Its target also omits the plaquette term. Do not count its simulated low gauge violation as measured UD evidence [7].

4. Raw-content audit: findings and limits

Waveform structure / reproducible PASS

The selected circuit file contains 1,000 rows, six metadata columns and 16,384 voltage samples per row. Channels 1-10 each have 100 records; the filename assigns nine oscillator signals and an empty tenth channel. All parsed values are finite. Sample rate is 1,953,125 Hz: interval 0.512 microseconds, record length 8.388608 ms, full-record FFT-bin spacing 119.2093 Hz. A bin width is not a confidence bound on a fitted frequency.

Acquisition identity and grouping

All ten channel groups share matching first-five metadata arrays. Frequency metadata spans 21-41 kHz in 100 distinct values, while recorded drive amplitude, phase and delay are zero. Therefore these must not automatically be treated as 100 independent repetitions of a single setting, or as a nonzero-drive sweep. Resolve that metadata distinction with the acquisition configuration before inferential fitting. Matching metadata does not establish clock-skew calibration.

Numerical sanity / not a calibration

Observed voltage range is -1.297863 to 1.243786 V, below the notebook's 15 V software clipping guard. That guard does not independently establish ADC headroom, linearity or voltage uncertainty. File SHA-256 is 7966700a6208e2bd2b5829a32b38cce7016f0c3460ace2708c85bac8577c282c. MD5 was used only to compare against published metadata, not as a modern integrity guarantee.

Extraction uncertainty

The notebook forms oscillator energies from voltage envelopes, uses frequency normalization for Gauss quantities and combines error terms in quadrature. Those operations need an explicit covariance model to justify correlated errors. The published extraction code's constants and peak/spline choices must be sensitivity-tested; channel gains, capacitor/frequency calibration, synchronization, feedback and filtering need a joint error record before a simultaneous interval claim.

Cold-atom audit flags

Two of nine lithium Fig.2 rows report zero error on mean. Never interpret those entries as exact, give them infinite inverse-variance weight, or invent an error floor without a declared sensitivity analysis. Yang's Fig.4 labels standard deviation, not guaranteed simultaneous error. Aggregated figure tables do not themselves supply shot-level covariance or the missing complex UD coherences.

Admission verdict

None of the audited datasets admits the full UD theorem: the circuit chain lacks UD topology, unitary rotor links, two-species target and plaquette term; quantum-link datasets use a different state space. No audited record supplies the full GPC/ERA/SDW preparation, actual energy and cumulative source-work package. This is a scoped finding about these records, not a proof that no suitable dataset exists anywhere.

5. Reanalysis and experiment requirements

Reanalysis that is justified next

For circuit data: freeze file/shot/channel identities; independently reconstruct envelopes and rotating-frame quadratures; reproduce published local Gauss curves and spectra; vary peak selection, time window and smoothing; estimate timing/gain/capacitance covariance; compare a calibrated gauge-invariant circuit model against detuned and gauge-breaking alternatives on held-out records. Fit the published circuit model, not UD mislabeled as that model. For atomic data: reproduce the reported population summaries with their stated error convention; obtain shot-level records before covariance-sensitive local tests.

First new experiment / component stage

Build and calibrate one closed diamond with two matter species and independently read signed electric channels. Check canonical rotor response, unit modulus, matter-link current, plaquette response, opposite-species convention and injected Gauss-source balance. A diamond is a component test, not the 15-node theorem. Proceed to the full 15/28/18 carrier only after those mappings and defect budgets are established.

Minimum experimental record

Save synchronized raw quadratures, rotor phases/electric values, channel and orientation maps, clock calibration, offsets/gains/nonlinearity and their covariance, independent preparation repeats, norm histories, applied coefficient schedules, feedback/drive/loss histories and outlier/saturation rules. Predeclare the energy/time conversion, target Hamiltonian, model discrepancy, hypothesis tests, held-out split and simultaneous-coverage construction. Acquire null controls with broken gauge coupling and controlled source injection.

Hard feasibility gate

Frozen endpoint bounds are sufficient, not necessary. At a=N=1 the inherited eta is 1/829538022; the SDW work allowance B/4 is approximately 3.30e-40 in model energy units. These cannot be called voltage, timing or energy tolerances without a calibrated map. Do not promise current hardware can meet them, or weaken them post hoc to claim theorem certification. Seek sharper bounds or test finite-amplitude predictions outside the certificate while labeling that scope honestly.

Promotion gates

Require an explicit canonical state/action/unit map; independently bounded model defects; all frozen initial and every-prefix gates; attributable non-constructor review; and independently acquired physical validation. Only then consider a narrowly scoped bridge receipt. Nominal action, coefficient ledger and existing theorem claims are unchanged. This report is not a new theorem manuscript and changes physical promotion by zero.

References and reproducibility

[1] Primary circuit paper

H. Riechert et al., Engineering a U(1) lattice gauge theory in classical electric circuits, Phys. Rev. B 105, 205141 (2022). DOI: 10.1103/PhysRevB.105.205141. Body/appendices inspected at https://arxiv.org/html/2108.01086v1 . The HTML rendering carries a later generated date; the paper is cited by its journal year and version identifier.

[2] Primary circuit data

https://doi.org/10.11588/DATA/6MEKHI . Metadata export used: https://heidata.uni-heidelberg.de/api/datasets/export?exporter=dataverse_json&persistentId=doi:10.11588/data/6MEKHI . Waveform DOI: https://doi.org/10.11588/DATA/6MEKHI/4PV8ZU .

[3] Author-linked code and data mirror

https://github.com/tychon/U1CircuitsData/tree/265b6671dde799d7c73f32247fa3ee93ae70e0f2 . The audited compressed file is in 05-21/. Code was inspected as text; acquisition programs and notebook cells were not executed. audit_waveform.py independently parses the selected file and emits WAVEFORM_AUDIT_v0.1.json.

[4-5] Yang experiment and dataset

B. Yang et al., Observation of gauge invariance in a 71-site Bose-Hubbard quantum simulator, Nature 587, 392-396 (2020): https://doi.org/10.1038/s41586-020-2910-8 . Public abstract, availability statement and figure metadata inspected; subscription-only body not accessed. Data: https://doi.org/10.7910/DVN/3RXD5F ; Fig.4 content: https://dataverse.harvard.edu/api/access/datafile/4013035 .

[6] Mil data and linked publication

A. Mil et al., A scalable realization of local U(1) gauge invariance in cold atomic mixtures, Science 367, 1128-1130 (2020), DOI 10.1126/science.aaz5312. Dataset: https://doi.org/10.5061/dryad.8gtht76k2 . Inspected file_stream IDs 219166, 219165 and 219164. Publication details are linked by the primary data repository; no claim of full Science-body inspection.

[7] Proposal exclusion

https://www.nature.com/articles/s42005-025-02144-8 . Full public body inspected to distinguish proposal/numerical calculations from experimental acquisition.

Provenance and scope

Audit date: 18 October 2026 UTC. Constructor: Codex, at user request. Frozen project base: 57c90583afae95fa8f91ce607194a507edbbf456; GPC, ERA and SDW v0.1 are conditional internal mathematical inputs, not external empirical evidence. No independent reviewer. Source inventories and inspected-text records accompany this report. No full corpus search, all-file replay, confidence interval or experimental validation is claimed.