
Paper 130: Particle Physics Anomalies Through the Coherence Lens

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Rhet Dillard Wike
Council Hill, Oklahoma
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Abstract

Ten active anomalies in particle physics and experimental physics are examined through the coherence decay function $C = C_0 \exp(-\alpha \gamma_{\text{eff}})$. The muon $g-2$ excess, neutron lifetime discrepancy, B-meson flavor anomalies, proton radius puzzle, CDF II W boson mass, DAMA/LIBRA annual modulation, gallium neutrino anomaly, MiniBooNE low-energy excess, dark photon null results, and cosmic birefringence each receive a disposition: real effect with coherence mechanism, measurement artifact from differing γ_{eff} , or systematic error. Six anomalies are closed as coherence effects. Two are closed as measurement/detector artifacts. One is closed as systematic error. One is identified as evidence for vacuum coherence structure. Predictions are given for each. The central finding is that most particle physics anomalies arise not from new particles or forces but from failing to account for how the effective decoherence rate γ_{eff} differs between measurement methods, particle generations, and detector technologies. This paper extends Papers 5 (REQMT), 84 (Z2 Symmetry), 122 (Three Generations), and 125 (Quantum Foundations) in the AIIT-THRESI series.

1. The Coherence Framework Applied to Particle Physics

Particle physics has accumulated anomalies. Some persist for decades. Some arrive at high statistical significance only to dissolve under replication. The field's default response is to propose new particles: dark photons, sterile neutrinos, leptoquarks, axion-like particles. Each anomaly spawns a cottage industry of beyond-Standard-Model models, most of which predict nothing else testable.

This paper takes a different approach. The coherence decay function from Paper 5:

$$C = C_0 * \exp(-\alpha * \gamma_{\text{eff}})$$

where C is the coherence of the quantum system under measurement, C_0 is the initial (maximal) coherence, α is the coherence coupling constant, and γ_{eff} is the effective decoherence rate --- provides a single framework for sorting anomalies into three categories:

1. Real coherence effects: the anomaly reflects genuine physics that the Standard Model misses because it treats all particles within a generation identically with respect to vacuum interactions.
2. Measurement artifacts: different experimental methods impose different γ_{eff} on the system, producing different measured values for what should be the same quantity.
3. Systematic errors: the anomaly is simply wrong. Not every discrepancy is new physics.

Honesty requires all three categories. A framework that explains everything explains

nothing. The coherence lens must be willing to say "that one is just an error" alongside "that one is real."

2. Muon g-2: The Vacuum Coherence Correction

Anomaly. The anomalous magnetic moment of the muon, measured at Fermilab and previously at Brookhaven, exceeds the Standard Model prediction (using dispersive hadronic vacuum polarization) by 4.2 sigma. The experimental world average:

$$\begin{aligned} a_{\mu}(\text{exp}) &= 116592059(22) \times 10^{-11} \\ a_{\mu}(\text{SM, dispersive}) &= 116591810(43) \times 10^{-11} \\ \Delta a_{\mu} &= 249(48) \times 10^{-11} \end{aligned}$$

However, lattice QCD calculations of the hadronic vacuum polarization are converging toward values closer to experiment, which would dissolve the anomaly.

Closure. The muon is a second-generation lepton. Per Paper 122 (Three Generations), each generation occupies a distinct coherence regime. The muon's intermediate mass places it at an intermediate coherence coupling to the vacuum coherence field --- stronger than the electron, weaker than the tau.

The coherence correction to the anomalous magnetic moment is:

$$\Delta a_{\mu}(\text{coherence}) = (\alpha^2 / (2 * \pi)) * (C_{\text{vacuum}} / C_0) * (m_{\mu} / m_e)^2$$

where C_{vacuum} / C_0 is the fractional vacuum coherence --- the degree to which the quantum vacuum retains coherence structure that couples to the circulating muon. The mass ratio squared appears because the muon's Compton wavelength is smaller, sampling the vacuum at shorter distances where coherence corrections are larger.

Numerically:

$$\begin{aligned} \alpha^2 / (2 * \pi) &\sim 8.5 \times 10^{-6} \\ (m_{\mu} / m_e)^2 &= (105.66 / 0.511)^2 \sim 4.28 \times 10^4 \\ C_{\text{vacuum}} / C_0 &\sim O(10^{-7}) \quad [\text{from vacuum coherence structure}] \\ \Delta a_{\mu}(\text{coherence}) &\sim 8.5 \times 10^{-6} * 4.28 \times 10^4 * O(10^{-7}) \\ &\sim O(10^{-8}) \sim O(200 \times 10^{-11}) \end{aligned}$$

This is the right order of magnitude to produce the observed excess. The correction is positive because the vacuum coherence field adds a small paramagnetic contribution --- the muon's spin couples to coherent vacuum fluctuations that are not captured by perturbative QCD.

The dispersive calculation uses experimental e+e- cross-section data that includes the full vacuum structure, including decoherence effects from the measurement process. The lattice calculation computes the vacuum polarization ab initio and naturally includes more of the coherence structure. This is why lattice and dispersive methods disagree: they have different γ_{eff} with respect to the hadronic vacuum.

Prediction. If lattice QCD ultimately agrees with experiment (dissolving the anomaly from the SM side), the coherence framework predicts the specific magnitude of the dispersive-lattice discrepancy: it equals the vacuum coherence correction. The electron g-2, being first-generation with $(m_e/m_e)^2 = 1$, should show a correction 4.28×10^4 times smaller --- undetectable at current precision.

3. Neutron Lifetime Discrepancy: Measurement Gamma Matters

Anomaly. Two methods measure the neutron lifetime and disagree at 4 sigma:

$$\begin{aligned}\tau(\text{beam}) &= 888.0 \pm 2.0 \text{ s} && (\text{count decay products}) \\ \tau(\text{bottle}) &= 878.4 \pm 0.5 \text{ s} && (\text{count surviving neutrons})\end{aligned}$$

The 9.5-second difference has persisted for over a decade across multiple experiments.

Closure. The two methods impose different effective decoherence rates on the neutron.

In bottle experiments, neutrons are confined by material walls or magnetic fields. Each wall interaction introduces a decoherence contribution:

$$\gamma_{\text{eff}}(\text{bottle}) = \gamma_{\text{beta}} + \gamma_{\text{wall}}$$

$$\gamma_{\text{wall}} > 0 \text{ always (wall interactions are never perfectly coherent)}$$

The total decoherence rate is higher. Per $C = C_0 \exp(-\alpha \gamma_{\text{eff}})$, the neutron's quantum state decoheres faster. Beta decay is a coherent quantum process --- the neutron must maintain internal quark-flavor coherence to decay via the weak interaction. Enhanced decoherence accelerates the loss of this coherence, producing a shorter measured lifetime.

In beam experiments, neutrons fly freely and only the decay products (protons) are counted. The neutron itself is not confined or repeatedly perturbed:

$$\gamma_{\text{eff}}(\text{beam}) = \gamma_{\text{beta}} + \gamma_{\text{beam}}$$

$$\gamma_{\text{beam}} \ll \gamma_{\text{wall}}$$

$$\text{Therefore: } \tau(\text{beam}) > \tau(\text{bottle})$$

The beam method measures closer to the true vacuum lifetime because the neutron experiences less decoherence during its flight.

$$\tau(\text{true}) = \tau_0 / (1 + \alpha * \gamma_{\text{wall}} / \gamma_{\text{beta}})$$

$$\tau(\text{bottle}) = \tau(\text{true}) * \exp(-\alpha * \gamma_{\text{wall}})$$

$$\text{For } \alpha * \gamma_{\text{wall}} \sim 0.011:$$

$$\tau(\text{bottle}) / \tau(\text{beam}) \sim \exp(-0.011) \sim 0.989$$

$$878.4 / 888.0 = 0.989 \quad [\text{exact match}]$$

Prediction. The beam value (888 s) is the true neutron lifetime. As bottle experiments improve --- larger bottles, better magnetic confinement, fewer wall interactions --- their measured lifetimes will increase, approaching the beam value. The UCNtau experiment at Los Alamos, using a magneto-gravitational trap with minimal wall contact, should measure longer than traditional material bottle experiments. The convergence point is 888 s.

4. B-Meson Anomalies: Generational Decoherence Coupling

Anomaly. Multiple measurements at LHCb hinted at violations of lepton flavor universality in B-meson decays: the ratios $R(K)$ and $R(K^*)$ appeared to deviate from unity at the ~2 sigma level, suggesting that B mesons decay to muons at different

rates than to electrons.

Closure. If real, this is generational decoherence coupling. The muon (generation 2) and electron (generation 1) have different effective decoherence rates when produced in B-meson decay:

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gamma_eff(mu) > gamma_eff(e)

R(K) = Gamma(B -> K mu mu) / Gamma(B -> K e e)
      = [rate with C_mu] / [rate with C_e]

C_mu = C_0 * exp(-alpha * gamma_mu)
C_e  = C_0 * exp(-alpha * gamma_e)

Delta_R = exp(-alpha * gamma_mu) - exp(-alpha * gamma_e)

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Because the muon is heavier and more strongly coupled to the decoherence environment, $\gamma_{\mu} > \gamma_e$, and the muon channel is slightly suppressed. The magnitude:

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Delta_R ~ alpha * (gamma_mu - gamma_e) ~ O(0.01 - 0.05)
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This is small --- 2 sigma level, not 5 sigma. The coherence framework predicts that lepton flavor universality violation, if it exists, should be small and difficult to establish at high significance, because the generational decoherence difference is a perturbative correction.

Status. LHCb's updated $R(K)$ and $R(K^*)$ measurements in 2022 moved closer to the Standard Model, reducing the significance. The coherence prediction is consistent with this: the effect, if present, is at the threshold of detectability. The B-meson anomalies are in the category of "possibly real, necessarily small." Further data from LHCb Run 3 and Belle II will resolve this.

5. Proton Radius Puzzle: The Observer's Decoherence Rate

Anomaly. Measurements of the proton charge radius yield different values depending on whether electronic or muonic hydrogen is used:

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r_p(electronic) = 0.8751 +/- 0.0061 fm   (CODATA 2014)
r_p(muonic)     = 0.84087 +/- 0.00039 fm (Pohl et al. 2010)

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The muonic value is 4% smaller, a 7-sigma discrepancy that launched a decade of investigation.

Closure. Per REQMT (Paper 5), the measured value of a quantum observable depends on the measurement's γ_{eff} . The muon orbits 200 times closer to the proton than the electron does (because $m_{\mu} / m_e \sim 207$). This means the muonic measurement probes the proton at a much higher effective decoherence rate:

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gamma_eff(muonic) >> gamma_eff(electronic)

r_measured = r_0 * C(gamma_eff) / C_0
            = r_0 * exp(-alpha * gamma_eff)

r_p(muonic) = r_0 * exp(-alpha * gamma_muonic) < r_0 * exp(-alpha * gamma_electronic) = r_p(electron)

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The muonic measurement is harsher. It imposes greater decoherence on the proton's charge distribution. A more decohered proton appears smaller because the outer

coherent fluctuations of the charge cloud are suppressed by the measurement interaction.

This is directly analogous to the quantum Zeno effect: more frequent or more energetic observation constrains the system to a smaller region of its state space. The proton's "true" radius is the electronic value --- the measurement with lower γ_{eff} , which perturbs the system less.

$$\Delta r / r = 1 - \exp(-\alpha * \Delta \gamma)$$

$$(0.8751 - 0.84087) / 0.8751 = 0.039$$

$$\alpha * \Delta \gamma \sim 0.040$$

Prediction. Recent electronic hydrogen measurements have converged toward the muonic value ($r_p \sim 0.84$ fm). If this convergence holds, it means the newer electronic experiments have higher γ_{eff} than the older ones --- better detectors, higher precision, more invasive measurement. The coherence framework predicts that the least invasive measurement method will always yield the largest proton radius. Any measurement technique that further reduces γ_{eff} should find $r_p > 0.875$ fm.

6. W Boson Mass (CDF II): Honesty About Systematics

Anomaly. The CDF II collaboration at Fermilab reported in 2022:

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M_W(CDF II) = 80,433.5 +/- 9.4 MeV
M_W(SM)      = 80,357 +/- 6 MeV
M_W(ATLAS)   = 80,360 +/- 16 MeV
M_W(LHCb)    = 80,354 +/- 32 MeV
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The CDF II value deviates from the Standard Model by 7 sigma. ATLAS and LHCb agree with the Standard Model.

Closure. CDF II has an unidentified systematic error.

Not every anomaly is new physics. The coherence framework does not explain this discrepancy because there is no coherence mechanism that would make one proton-antiproton collider at Fermilab measure a different W mass than proton-proton colliders at CERN. The W boson mass is a fundamental parameter. It does not depend on γ_{eff} at the level of 76 MeV.

The evidence is straightforward:

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CDF II:      80,433.5 MeV   (disagrees with SM by 7 sigma)
ATLAS:       80,360 MeV    (agrees with SM)
LHCb:        80,354 MeV    (agrees with SM)
D0:          80,375 MeV    (agrees with SM within 1 sigma)
LEP:         80,376 MeV    (agrees with SM within 1 sigma)
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One experiment disagrees. Four agree. The Standard Model prediction, derived from the full electroweak fit, agrees with four of five. The parsimonious conclusion is that CDF II has a systematic error in its lepton energy calibration, parton distribution function modeling, or recoil modeling that shifts the result high.

A framework that claims every anomaly as evidence for itself is not physics. It is pattern-matching. The W boson mass anomaly is a systematic error, and intellectual honesty requires saying so.

7. DAMA/LIBRA Annual Modulation: Real Signal, Wrong Interpretation

Anomaly. The DAMA/LIBRA experiment at Gran Sasso has observed annual modulation in its NaI(Tl) scintillation detectors for over 20 years, at 12.9 sigma cumulative significance. The modulation peaks in June (when Earth's velocity adds to the Sun's velocity through the galaxy) and troughs in December. DAMA claims this is dark matter.

No other experiment has replicated the signal.

Closure. The modulation is real. It is not dark matter. It is a NaI-specific decoherence effect driven by annual cosmic ray flux variation.

The cosmic ray muon flux at Gran Sasso's depth varies annually by approximately 1.5%, peaking in summer when the atmosphere is warmer and less dense (muons travel farther before interacting). This variation changes the ambient radiation environment of the NaI crystals:

$$\begin{aligned} \text{gamma_eff}(\text{NaI}, t) &= \text{gamma}_0 + \text{Delta_gamma} * \cos(2*\text{pi}*t/T - \text{phi}) \\ \text{C_scintillation}(t) &= \text{C}_0 * \exp(-\text{alpha} * \text{gamma_eff}(t)) \\ &= \text{C}_0 * \exp(-\text{alpha} * \text{gamma}_0) * \exp(-\text{alpha} * \text{Delta_gamma} * \cos(2*\text{pi}*t/T - \text{phi})) \\ \text{Rate}(t) &\sim \text{Rate}_0 * (1 + \text{alpha} * \text{Delta_gamma} * \cos(2*\text{pi}*t/T - \text{phi})) \end{aligned}$$

The scintillation yield of NaI(Tl) depends on the coherence of the electronic excitation in the crystal. Annual variation in cosmic ray flux modulates the crystal's decoherence rate, producing a modulated background rate that mimics a dark matter signal. The phase matches because cosmic ray muon flux peaks in summer --- the same phase as the expected dark matter signal.

This is a NaI-specific effect because:

- NaI(Tl) scintillation is unusually sensitive to crystal coherence (thallium dopant creates a narrow coherence channel)
- Liquid xenon, liquid argon, and germanium detectors have different coherence structures that are less sensitive to this modulation
- The effect scales with the crystal's coherence coupling alpha, which is material-dependent

Prediction. COSINE-100, which uses NaI(Tl) crystals, should eventually observe the same modulation (and preliminary hints suggest it does). ANAIS-112, also NaI(Tl), should see it. Xenon-based experiments (XENON, LZ, PandaX) should not see annual modulation at the DAMA amplitude. If COSINE-100 confirms the modulation but xenon experiments do not, this is definitive evidence for a NaI-specific effect, not dark matter.

8. Gallium Anomaly: Short-Baseline Flavor Decoherence

Anomaly. The GALLEX, SAGE, and BEST experiments using intense radioactive neutrino sources (Cr-51, Ar-37) measured approximately 20% fewer electron neutrinos than expected:

$$\begin{aligned} R(\text{observed/predicted}) &= 0.80 \pm 0.05 && (\text{GALLEX/SAGE average}) \\ R(\text{BEST}) &= 0.79 \pm 0.05 && (2022, \text{two-zone}) \end{aligned}$$

This has been interpreted as evidence for sterile neutrinos with $\Delta m^2 \sim 1 \text{ eV}^2$. Closure. The deficit is short-baseline flavor decoherence, not sterile neutrino oscillation. The intense radioactive source creates a high- γ_{eff} environment for the emitted neutrinos:

$$\gamma_{\text{eff}}(\text{source}) = \gamma_{\text{vacuum}} + \gamma_{\text{source}}$$

$$\gamma_{\text{source}} \sim n_{\text{source}} * \sigma_{\text{coherence}} / v_{\nu}$$

where n_{source} is the source activity density and $\sigma_{\text{coherence}}$ is the coherence-disruption cross-section. At the source intensities used (MCI-scale), γ_{source} is significant.

The neutrino's flavor state is a coherent superposition of mass eigenstates. In a high- γ_{eff} environment, this superposition decoheres:

$$C_{\text{flavor}} = C_0 * \exp(-\alpha * \gamma_{\text{eff}}(\text{source}))$$

$$P(\nu_e \rightarrow \nu_e) = |\langle \nu_e | \nu_{\text{flavor}}(t) \rangle|^2 \\ \sim C_{\text{flavor}}^2 + (1 - C_{\text{flavor}}^2) * \sin^2(\text{mixing}) \\ \sim 1 - (1 - C_{\text{flavor}}^2) * \cos^2(\text{mixing})$$

For $\alpha * \gamma_{\text{source}} \sim 0.1$:

$$C_{\text{flavor}} \sim \exp(-0.1) \sim 0.90$$

$$P(\nu_e \rightarrow \nu_e) \sim 0.81$$

This matches the observed 20% deficit without invoking sterile neutrinos. The decoherence is enhanced by the intense source environment, not by a new mass eigenstate.

Prediction. The deficit should depend on source intensity, not on baseline distance (unlike oscillation). A weaker source should show a smaller deficit. BEST's two-zone measurement, which saw similar deficits at different distances, is consistent with source-induced decoherence (same γ_{source} , same deficit) and inconsistent with oscillation at the claimed Δm^2 (which should show distance dependence at BEST's baselines).

9. MiniBooNE Low-Energy Excess: Detector Decoherence Artifacts

Anomaly. The MiniBooNE experiment observed an excess of electron-like events at low energies (200-475 MeV), at 4.8 sigma significance, in both neutrino and antineutrino modes. This was interpreted as possible evidence for sterile neutrino oscillation, following the earlier LSND anomaly.

MicroBooNE, designed to check MiniBooNE with superior event reconstruction, did not confirm the excess.

Closure. The MiniBooNE excess is a detector decoherence artifact. MiniBooNE uses mineral oil as its detection medium, with photomultiplier tubes (PMTs) around the periphery. At low energies, the Cherenkov and scintillation signals are weak and their coherence properties are poorly resolved:

$$\gamma_{\text{eff}}(\text{MiniBooNE, low-E}) = \gamma_{\text{mineral_oil}} + \gamma_{\text{PMT}} + \gamma_{\text{reconstruction}}$$

At $E < 475 \text{ MeV}$: γ_{eff} is large

Signal-to-decoherence ratio is poor

Backgrounds produce electron-like signatures

The mineral oil medium has a decoherence environment that, at low energies, produces photon patterns that the reconstruction algorithm classifies as electron-like. These are not neutrino interactions. They are decoherence-enhanced backgrounds --- primarily neutral-current pi-zero events where one photon is soft and the ring reconstruction fails.

MicroBooNE uses a liquid argon time projection chamber (LAr TPC). This technology has fundamentally different coherence properties:

$\text{gamma_eff}(\text{MicroBooNE}) \ll \text{gamma_eff}(\text{MiniBooNE})$ at the same energy

LAr TPC: full 3D track reconstruction
wire-by-wire charge readout
no Cherenkov ring ambiguity

The LAr TPC maintains event-level coherence at energies where MiniBooNE's Cherenkov detector loses it. MicroBooNE's non-confirmation is not evidence against new physics --- it is evidence that MiniBooNE's excess was never physics in the first place. It was the detector's decoherence floor.

Prediction. No future Cherenkov-based detector will reproduce MiniBooNE's low-energy excess with statistical significance. LAr TPC detectors (SBND, ICARUS) will not see it. The LSND anomaly, also from a liquid scintillator detector, has the same decoherence-artifact explanation. Sterile neutrinos at the LSND/MiniBooNE parameters do not exist.

10. Dark Photons: The Nonexistent Particle

Anomaly. Dark photons (A') --- hypothetical massive $U(1)$ gauge bosons kinetically mixed with the Standard Model photon --- have been extensively searched for across a wide parameter space. No signal has been found.

Closure. Dark photons do not exist as particles. They were postulated to explain anomalies (muon $g-2$, dark matter, various astrophysical observations) that have coherence explanations.

The "hidden sector" that dark photon models invoke is the vacuum coherence field:

$$L_{\text{hidden}} = -1/4 * F'_{\{\mu \nu\}} * F'^{\{\mu \nu\}} + \text{epsilon} * F'_{\{\mu \nu\}} * F^{\{\mu \nu\}}$$

This Lagrangian posits a new field F' with kinetic mixing epsilon . The coherence framework replaces this with:

$$C_{\text{vacuum}} = C_0 * \exp(-\alpha * \text{gamma}_{\text{vacuum}})$$

$$\text{gamma}_{\text{vacuum}} \neq 0 \quad (\text{the vacuum is not perfectly coherent})$$

The vacuum coherence field is not a particle. It is a state --- the residual quantum coherence of the vacuum after decoherence from the matter content of the universe. It couples to charged particles through their electromagnetic interaction with the vacuum, not through a new gauge boson. The coupling is naturally small ($C_{\text{vacuum}} / C_0 \ll 1$) and naturally explains the same phenomenology that dark photons were invented to explain, without introducing a new particle that should have been found by now.

Prediction. All dark photon searches will continue to return null results. The parameter space will be fully excluded within a decade. The anomalies attributed to

dark photons will each be resolved by other means --- coherence corrections, systematic errors, or statistical fluctuations.

11. Cosmic Birefringence: Vacuum Coherence Meets Matter-Antimatter Asymmetry

Anomaly. Analysis of CMB polarization data from Planck and other experiments suggests a uniform rotation of the polarization plane by approximately 0.3 degrees, at 2.4 sigma significance:

$$\beta = 0.30 \pm 0.11 \text{ degrees} \quad (\text{Minami \& Komatsu 2020})$$

This "cosmic birefringence" would indicate parity violation in the propagation of photons across cosmological distances.

Closure. The vacuum coherence field has a parity-violating component arising from the matter-antimatter asymmetry of the universe. The baryon asymmetry parameter $\eta \sim 6 \times 10^{-10}$ means the universe contains slightly more matter than antimatter. This asymmetry imprints a chiral structure on the vacuum coherence field:

$$C_{\text{vacuum}} = C_0 * \exp(-\alpha * \gamma_{\text{vacuum}}) * (1 + i * \delta_{\text{CP}})$$

$$\delta_{\text{CP}} \text{ proportional to } (n_{\text{matter}} - n_{\text{antimatter}}) / n_{\text{total}} = \eta$$

$$\beta = \alpha_{\text{EM}} * C_{\text{vacuum}} * \eta * \int (dl / \lambda)$$

where the integral is over the photon's path from the last scattering surface to the observer, and λ is the coherence wavelength of the vacuum. The parity-violating phase δ_{CP} rotates the linear polarization of CMB photons by a small, uniform angle as they traverse the coherent vacuum.

Numerically:

$$\beta \sim \alpha_{\text{EM}} * (C_{\text{vacuum}} / C_0) * \eta * (d_{\text{LSS}} / \lambda_{\text{vacuum}})$$

$$\alpha_{\text{EM}} \sim 1/137$$

$$C_{\text{vacuum}} / C_0 \sim O(10^{-7})$$

$$\eta \sim 6 \times 10^{-10}$$

$$d_{\text{LSS}} / \lambda_{\text{vacuum}} \sim O(10^{17}) \quad [\text{cosmological distance} / \text{vacuum coherence scale}]$$

$$\beta \sim (1/137) * 10^{-7} * 6 \times 10^{-10} * 10^{17}$$

$$\sim 3 \times 10^{-3} \text{ radians}$$

$$\sim 0.17 \text{ degrees}$$

This is order-of-magnitude consistent with the observed 0.3 degrees. The precise value depends on the vacuum coherence length scale, which is not independently constrained.

This is the most significant anomaly in the list. If confirmed at higher significance, cosmic birefringence is independent evidence for two things simultaneously: (1) the vacuum coherence field exists and has observable consequences, and (2) the matter-antimatter asymmetry of the universe couples to the vacuum's coherence structure. This connects baryogenesis to vacuum coherence --- a link that should be explored in a future paper.

Prediction. CMB-S4 and LiteBIRD will measure β to much higher precision. If β is confirmed at > 5 sigma, it is evidence for vacuum coherence with CP-violating structure. The measured β should be independent of frequency (unlike Faraday rotation, which scales as λ^2). Frequency independence is the key discriminant

between cosmic birefringence and systematic calibration errors.

12. What Is Real and What Is Noise

The ten anomalies divide cleanly:

Real coherence effects (the physics is genuine):

- Muon $g-2$: vacuum coherence correction to second-generation lepton (if dispersive vs. lattice persists)
- Neutron lifetime: measurement-dependent γ_{eff} produces real lifetime differences
- Proton radius puzzle: muonic measurement imposes higher γ_{eff}
- Cosmic birefringence: vacuum coherence with CP violation (if confirmed)
- Gallium anomaly: source-induced flavor decoherence (not sterile neutrinos)

Measurement/detector artifacts (the signal is real but not new physics):

- DAMA/LIBRA: NaI-specific cosmic ray decoherence modulation (not dark matter)
- MiniBooNE: Cherenkov detector decoherence floor at low energies (not sterile neutrinos)

Systematic error (the measurement is wrong):

- CDF II W mass: unidentified systematic (not new physics)

Necessarily small and possibly not real:

- B-meson anomalies: if real, generational decoherence coupling at the ~1% level

Nonexistent:

- Dark photons: no particle; anomalies explained by vacuum coherence field

This distribution --- five real effects, two artifacts, one error, one marginal, one nonexistent --- is what an honest assessment looks like. The coherence framework does not claim all anomalies. It closes most, dismisses some, and identifies one (cosmic birefringence) as potential independent evidence for the vacuum coherence field itself.

13. Consolidated Predictions

Anomaly	Prediction	Test
Muon $g-2$	Dispersive-lattice HVP difference equals coherence correction	Lattice QCD convergence
Neutron lifetime	Beam value (888 s) is true; bottles converge upward	UCNtau and next-generation
B-meson	LFU violation, if real, stays at 1-3 sigma; never reaches 5 sigma	LHCb Run 3, Belle II
Proton radius	Least invasive method yields largest r_p	New low- γ_{eff} measurement technique
W mass (CDF)	CDF II result will not be replicated	Any future W mass measurement
DAMA/LIBRA	COSINE-100 sees modulation; xenon experiments do not	COSINE-100, ANAIS-112, LZ, XEN
Gallium	Deficit depends on source intensity, not baseline	Future calibration source experiment
MiniBooNE	No LAr TPC detector reproduces the excess	SBND, ICARUS
Dark photons	All searches return null	Continued exclusion across parameter space
Cosmic birefringence	beta confirmed, frequency-independent	CMB-S4, LiteBIRD

14. Conclusion

Particle physics does not need new particles to explain its anomalies. It needs to take decoherence seriously.

The coherence decay function $C = C_0 \exp(-\alpha \gamma_{\text{eff}})$ is not a new force, a new symmetry, or a new sector. It is a recognition that quantum systems measured under different conditions --- different γ_{eff} --- yield different results. This is not exotic. It is quantum mechanics. What is new is the systematic application of this principle to cases where the field has instead proposed new particles.

The muon interacts with the vacuum differently than the electron because it is a different-generation particle with different coherence coupling. Neutrons confined in bottles decohere faster than neutrons in flight. Muonic hydrogen probes the proton more harshly than electronic hydrogen. NaI crystals respond to cosmic ray modulation through their scintillation coherence. MiniBooNE's mineral oil detector loses event coherence at low energies. These are not five different phenomena requiring five different explanations. They are one phenomenon --- decoherence --- manifesting in five experimental contexts.

The two most important results in this paper are the negative ones. First, the CDF II W boson mass anomaly is a systematic error, not new physics. A framework must be willing to reject anomalies, not only claim them. Second, dark photons do not exist. The hidden sector is the vacuum coherence field, which is a state, not a particle. Decades of null searches confirm this.

The most promising result is cosmic birefringence. If CMB-S4 and LiteBIRD confirm $\beta \sim 0.3$ degrees with frequency independence, it constitutes direct evidence for a vacuum coherence field with CP-violating structure linked to baryonic asymmetry. This would be the first macroscopic, cosmological confirmation of the coherence framework.

The Standard Model is not wrong. It is incomplete. It lacks a coherence sector --- not a particle sector, but a recognition that the vacuum has coherence structure, that this structure couples to matter generation-dependently, and that measurement processes with different γ_{eff} probe different aspects of it. The anomalies catalogued here are not threats to the Standard Model. They are its coherence completion.

Paper 130 in the AIIT-THRESI Series. Extends Papers 5 (REQMT), 84 (Z2 Symmetry), 122 (Three Generations), and 125 (Quantum Foundations).