TFPT Unconventional Test Results

Unconventional Suite: Search/Audit/Conjecture tooling for TFPT.

This PDF contains the results of the **Unconventional Suite**, which consists of 7 modules. These modules are **not** publication-grade physics derivations, but rather tools to accelerate closing ToE gaps (GA search, enumeration, metamorphic tests).

Content: Each module is grouped by its theoretical question and provides search/audit/design tools for specific TFPT aspects. The results serve exploration and finding solution paths, not final verification.

Difference from other variants: In contrast to the Conventional Suite (Engineering/Physics), this suite focuses on experimental search procedures and design tools, not on deterministic verification.

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Output directory: `tfpt-suite/out/unconventional`

Module Overview

Group	Module	Title	Checks	Status
A. Matching & Threshold Robustness	ux_matching_metamorphic_audit	Unconventional: matching metamorphic audit (invertibility + stability)	2/2	OK
A. Matching & Threshold Robustness	ux_threshold_graph_audit	Unconventional: threshold graph audit (segments + matching bookkeeping)	10/10	OK
B. k->I Bridge Feasibility	ux_cosmo_history_sampler	Unconventional: cosmology history sampler (k->I feasibility + robustness)	9/9	OK
C. Flavor Convention Search	ux_flavor_holdout_search	Unconventional: flavor holdout search (discrete CKM phase-map conventions)	3/3	OK
D. Gravity Gauge-Fixing	ux_gravity_gaugefix_ga	Unconventional: gravitation gauge-fixing GA (toy nonminimal -> Laplace-type)	4/4	OK
E. Omegab-APS Bridge	ux_omega_b_aps_bridge	Unconventional: Omega_b coefficient bridge via APS seam term (DeltaGamma)	5/5	OK
F. Torsion Regime Design	ux_torsion_regime_designer	Unconventional: torsion regime designer (spin-polarized medium + bound saturation targets)	2/2	OK

A. Matching & Threshold Robustness

Question: Are the matching primitives and threshold transitions correctly implemented?

1. Unconventional: matching metamorphic audit (invertibility + stability)

Module ID: `ux_matching_metamorphic_audit` | **Output:** `tfpt-suite/out/unconventional/ux_matching_metamorphic_audit`

Objective

Purpose: This module implements **metamorphic / property-style audits** for the low-level matching primitives in:

- `tfpt_suite/matching.py`

It is an **engineering hardening layer**: it does *not* add physics content, but it reduces the risk of silent regressions and makes the ?scheme/threshold bookkeeping? reviewer-proof.

Why this matters for ?ToE closure?: In `tfpt-suite/progress.md`, a key publication-grade gap is **renormalization + threshold matching**:

- finite matching pieces at thresholds (beyond ?identity at mu=M?)
- uncertainty propagation across thresholds/policies
- stable, explicit APIs (`match_gauge`, `match_yukawa`, `match_quartic`)

Before adding more physics, we want strong evidence that the matching plumbing behaves as intended.

This module addresses that by verifying **metamorphic invariants** such as:

- **Invertibility (approx/exact)**:
- alphas quark threshold: `down(up(alpha3)) ~ alpha3` (series-truncation-level)
- gauge matching with finite deltaalpha: `down(up(g_i, deltaalpha)) = g_i` (should be exact up to float rounding)
- **Stability**:
- matching never produces negative alpha for the sampled deltaalpha range

Methodology

What the module computes: - A deterministic set of random samples (seeded by `SuiteConfig.seed`)
- For each property, it computes:
- max absolute error
- max relative error
- the worst-case sample (inputs + outputs)
- The module returns explicit `checks[]` that fail if errors exceed conservative tolerances.

Checks

Check	Severity	Detail
alpha3_threshold_up_down_near_identity	PASS	`max_rel_err=2.211e-16 (tol=1.0e-05); max_abs_err=5.551e-17; samples=500`
match_gauge_finite_delta_up_down_identity	PASS	`max_rel_err=3.075e-16 (tol=1.0e-12); max_abs_err=4.441e-16; samples=400`

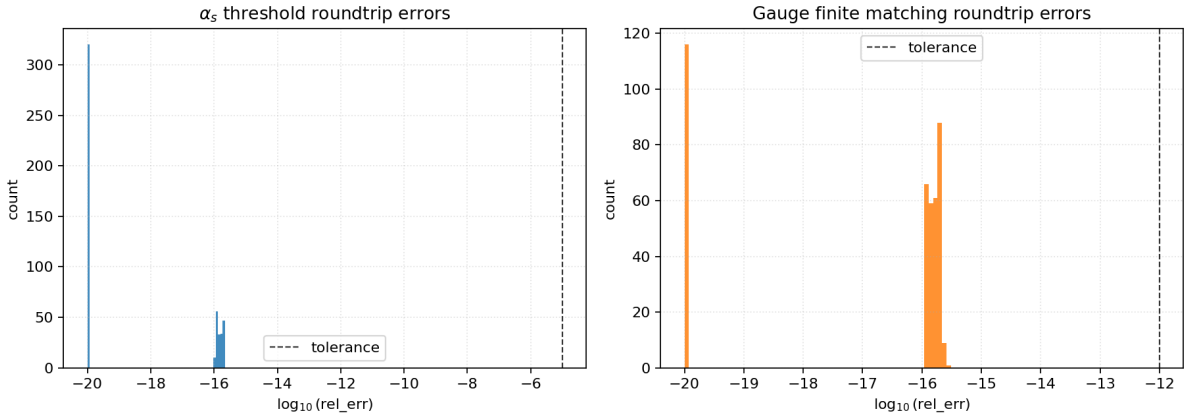
Results (report.txt)

```
Unconventional: matching metamorphic audit

Goal:
- Harden the matching layer by verifying metamorphic properties (invertibility/stability).
- This is a math/engineering audit; it does not add new physics content.

Samples: alpha3=500, gauge=400

Results:
- alpha3 threshold: max_abs_err=5.551115e-17, max_rel_err=2.210860e-16
```

```
- gauge finite matching: max_abs_err=4.440892e-16, max_rel_err=3.075434e-16

Worst cases:
- alpha3: _WorstCase(label='alpha3_threshold_up_then_down', inputs={'alpha3': 0.271628125627}, outputs={'alpha3_up':
0.271318953139, 'alpha3_back': 0.271628125627}, abs_error=5.55111512313e-17, rel_error=2.04364518965e-16)
- gauge:  _WorstCase(label='match_gauge_finite_delta_up_then_down', inputs={'gY': 0.230732794729, 'g2':
0.439191452894, 'g3': 1.44398857327, 'dalphaY': -7.68382382367e-06, 'dalpha2': 6.41402901711e-06, 'dalpha3':
8.68898652304e-06}, outputs={'gY_up': 0.230523458211, 'g2_up': 0.439283204051, 'g3_up': 1.44402638091,
 'gY_back': 0.230732794729, 'g2_back': 0.439191452894, 'g3_back': 1.44398857327}, abs_error=4.4408920985e-16,
 rel_error=3.07543437718e-16)

Checks:
- alpha3_threshold_up_down_near_identity: PASS (max_rel_err=2.211e-16 (tol=1.0e-05); max_abs_err=5.551e-17; samples=500)
- match_gauge_finite_delta_up_down_identity: PASS (max_rel_err=3.075e-16 (tol=1.0e-12); max_abs_err=4.441e-16; samples=400)

Notes:
- `match_alpha3_quark_threshold_2loop` is a truncated series: exact invertibility is not expected.
- `match_gauge` with `finite_delta_alpha` is explicit by construction: up+down should invert within float rounding.
```

Plots

`matching_metamorphic_errors.png`



2. Unconventional: threshold graph audit (segments + matching bookkeeping)

Module ID: `ux_threshold_graph_audit` | **Output:** `tfpt-suite/out/unconventional/ux_threshold_graph_audit`

Objective

Purpose: This module addresses `tfpt-suite/unconventional/tasks.md` (Section B) deliverable:

- **a declarative threshold graph**: which theory/model is active in which \(\mu\)-interval, and what ?matching actions? happen at boundaries.

The main suite?s 2-loop runner already implements this declaratively via:

- `tfpt_suite/rge_pyrate_2loop.py`
- `threshold_rules` (what happens at each threshold)
- `segments` (piecewise integration with explicit segment metadata)

This unconventional module extracts that into a standalone, inspectable artifact and compares:

- **matching disabled** (segments labeled ?continuous_by_assumption?)
- **matching enabled** (explicit `match_gauge/match_yukawa/match_quartic` outcomes recorded; 1-loop is identity at mu=threshold)

Methodology

Inputs: - Threshold table: `tfpt-suite/tfpt_suite/data/rge_thresholds_v25.json`
- SM boundary at \(m_t\): derived deterministically from `tfpt-suite/tfpt_suite/data/sm_inputs_mz.json` via `tfpt_suite/pyrate_boundary_runner.py` (PyR@TE-driven MZ->mt, RG-authority compliant)

- PyR@TE beta sources from `tfpt-suite/tfpt_suite/data/pyrate_pythonoutputs.json`

Additionally (Gate-2 matching audit):

- below-MZ heavy-quark thresholds `mc_GeV, mb_GeV` from `sm_inputs_mz.json`, used to verify finite 2-loop \(\alpha_s\) decoupling when `apply_alpha3_matching=True`.

What it computes: - **Nodes**: thresholds (sorted), e.g. MSigma, MG8, MNR1..3
- **Edges**: segments \([\mu_\mathrm{start},\mu_\mathrm{end}]\) with:
- active model (`sm_tfpt_2loop_v25` or `e8_sigma_yN_2loop`)
- active patches (e.g. `delta_b3_g8`, `gravity_alpha3` if enabled)
- threshold transition at segment start (if any)
- matching record (enabled/disabled)
- **Threshold status** (matching ON): `finite_pieces_implemented` vs `identity_matching`, based on recorded `match_gauge`/`match_yukawa`/`match_quartic` outcomes.

Checks

Check	Severity	Detail
threshold_table_loaded	PASS	nodes=[('MSigma', 1000.0), ('MG8', 18000000000.0), ('MPhi', 88600000000.0), ('MNR1', 1000000000000000.0), ('MNR2', 3000000000000000.0), ('MNR3', 8000000000000000.0)]
segments_ordered_matching_off	PASS	segments=6
segments_ordered_matching_on	PASS	segments=6
segment_count_matches_expected	PASS	expected=6 from thresholds_in_range=['MSigma', 'MG8', 'MNR1', ' MNR2', 'MNR3']; got=6
matching_off_marks_blocked_thresholds	PASS	publication_grade={'threshold_matching_ok': False, ' blocked_thresholds': ['MSigma', 'MG8', 'MNR1', 'MNR2', 'MNR3'], ' note': "Publication-grade threshold bookkeeping requires matching_active=True at...
matching_on_is_publication_grade_bookkeeping	PASS	publication_grade={'threshold_matching_ok': True, ' blocked_thresholds': [], 'note': "Publication-grade threshold bookkeeping requires matching_active=True at each threshold boundary; if matching is...
thresholds_marked_publication_grade	PASS	threshold_statuses=[{'threshold_id': 'MSigma', 'status': ' identity_matching', 'component_status': {'gauge': ' matched_1loop_log_only_identity', 'yukawa': ' matched_1loop_log_only_identity', 'quartic'...
matching_on_no_blocked_thresholds	PASS	blocked_thresholds=[]
threshold_starts_have_explicit_matching_records_when_enabled	PASS	threshold_segments=5, matching_active_true=5
below_mz_alpha3_matching_changes_alpha_s	PASS	alpha_s(mc) off=0.346914414, on=0.347983505, delta=+1.069e-03

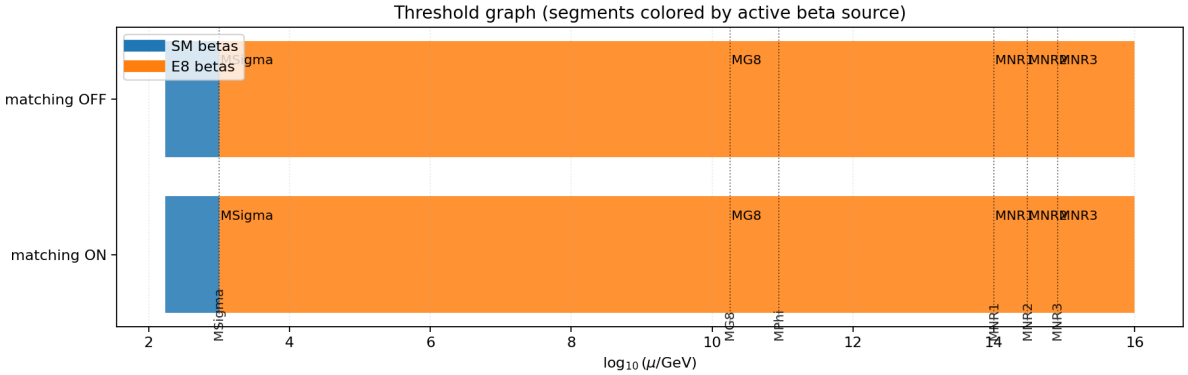
Results (report.txt)

```
Unconventional: threshold graph audit

Purpose:
- Provide an explicit, inspectable segment/threshold graph for the 2-loop RGE runner.
- Compare matching disabled vs enabled bookkeeping (identity-at-threshold at 1-loop, but explicit).

Threshold table: tfpt-suite/tfpt_suite/data/rge_thresholds_v25.json
mt boundary: mt=172.76 GeV (from sm_boundary_conditions_at_mt, route_2loop)
mu_uv: 1e+16 GeV

Threshold nodes (sorted):
- MSigma: 1000 GeV
- MG8: 1.8e+10 GeV
- MPhi: 8.86e+10 GeV
- MNR1: 1e+14 GeV
- MNR2: 3e+14 GeV
- MNR3: 8e+14 GeV

Edges (matching OFF):
- [172.76 -> 1000] model=sm_tfpt_2loop_v25 patches=[] thr_at_start=None matching_active=None
- [1000 -> 1.8e+10] model=e8_sigma_yN_2loop patches=[] thr_at_start=MSigma matching_active=False
- [1.8e+10 -> 1e+14] model=e8_sigma_yN_2loop patches=['delta_b3_g8'] thr_at_start=MG8 matching_active=False
- [1e+14 -> 3e+14] model=e8_sigma_yN_2loop patches=['delta_b3_g8'] thr_at_start=MNR1 matching_active=False
- [3e+14 -> 8e+14] model=e8_sigma_yN_2loop patches=['delta_b3_g8'] thr_at_start=MNR2 matching_active=False
```

```
- [8e+14 -> 1e+16] model=e8_sigma_yN_2loop patches=['delta_b3_g8'] thr_at_start=MNR3 matching_active=False

Edges (matching ON):
- [172.76 -> 1000] model=sm_tfpt_2loop_v25 patches=[] thr_at_start=None matching_active=None
- [1000 -> 1.8e+10] model=e8_sigma_yN_2loop patches=[] thr_at_start=MSigma matching_active=True
- [1.8e+10 -> 1e+14] model=e8_sigma_yN_2loop patches=['delta_b3_g8'] thr_at_start=MG8 matching_active=True

... (truncated, see report.txt for full output) ...
```

Plots

threshold_graph.png



B. k->l Bridge Feasibility

Question: Can the bounce reach CMB multipoles under plausible priors?

3. Unconventional: cosmology history sampler (k->l feasibility + robustness)

Module ID: `ux_cosmo_history_sampler` | **Output:** `tfpt-suite/out/unconventional/ux_cosmo_history_sampler`

Objective

Purpose: This module explores the **k->l bridge feasibility** by sampling explicit expansion-history parameters and computing the resulting bounce multipole location.

It is intentionally **not a ?fit?**. The search space is defined by explicit priors (ranges), and the output is a **robustness statement**:

- under these declared priors, does the bounce feature land in the CMB l window?
- if not, what l range is robustly implied (small-scale prediction)?

Why this matters for ?ToE closure?: `tfpt-suite/progress.md` flags the k->l bridge as a key open closure item:

- `k_calibration` quantifies the missing overall scaling
- what is still missing is a **publication-grade expansion history policy/module** that deterministically yields $a_0/a_{\mathrm{transition}}$
- the project must decide whether TFPT predicts **CMB-visible** bounce features or **small-scale-only** features

This module is the ?unconventional? complement to `k_calibration`:

- `k_calibration` is deterministic for a fixed policy input
- this module probes **policy sensitivity** and feasibility under explicit priors

Methodology

What the module computes: Inputs (aligned with the main suite):

- bounce scale $k_{\mathrm{bounce}}^{s,t}$:
- prefers `tfpt-suite/out/bounce_perturbations/results.json` if present
- otherwise uses the fallback values in `tfpt_suite/data/k_calibration.json`
- cosmology snapshot (flat LambdaCDM) from `tfpt_suite/data/k_calibration.json`
- scale-factor mapping in `tfpt_suite/cosmo_scale_map.py`:
- entropy mapping after reheating
- optional reheating expansion `exp(N_reheat)`
- inflation expansion `exp(N_inflation_from_transition)`

For each scenario (set of priors), it samples:

- `N_inflation_from_transition`
- `N_reheat`
- `T_reheat_GeV` (log-uniform prior)

Additionally, the module includes a **policy-driven scenario** (`policy_v106_threshold_driven`) that reduces free knobs:

- N_{pivot} is derived from `global_reference_minimal.json` via the Starobinsky relation $N\simeq 2/(1-n_s)$
- N_{reh} is derived from T_{reh} via the v1.06 reheating ρ-scaling model (`cosmo_reheating_policy_v106.json`), including the declared ΔN floor filter

and computes:

- $a_0/a_{\mathrm{transition}}$

- \(\ell_{\mathrm{bounce}}^{s,t}\)
- fraction of samples with \(\ell\) in a diagnostic ?CMB window? (default: \([2,2500]\))
- best candidates closest to target l values (in log-space)

Checks

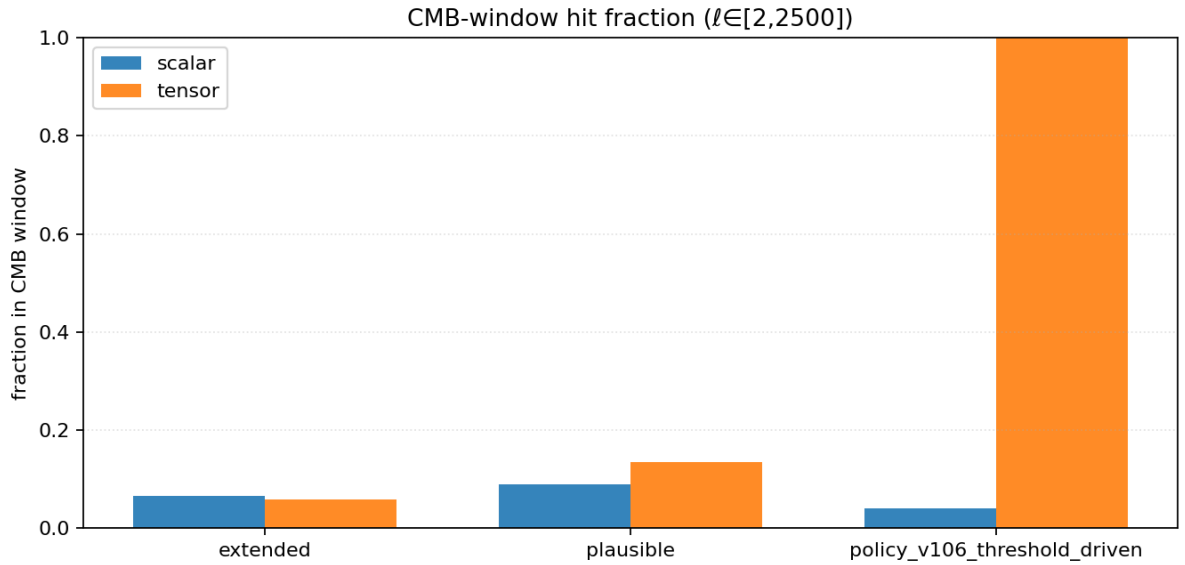
Check	Severity	Detail
bounce_source_resolved	PASS	bounce_source=live: /Users/stefanhamann/Projekte/wolfram_latex_attachments/tfpt-suite/out/bounce_perturbations/results.json; k_bounce_s_raw=2103.5507357951246; k_bounce_t_raw=7.80803964429
chi_star_computed	PASS	chi_star(z*=1090.0)=13867.328 Mpc (flat LambdaCDM)
naive_ell_is_huge_as_expected	PASS	ell_naive scalar=1.396e+59, tensor=5.180e+56
policy_v106_threshold_driven_has_any_scalar_in_cmb_window	PASS	fraction=0.03977 (41/1031) in lin[2.0,2500.0]
policy_v106_threshold_driven_has_any_tensor_in_cmb_window	PASS	fraction=1 (1031/1031) in lin[2.0,2500.0]
plausible_has_any_scalar_in_cmb_window	PASS	fraction=0.08925 (357/4000) in lin[2.0,2500.0]
plausible_has_any_tensor_in_cmb_window	PASS	fraction=0.1345 (538/4000) in lin[2.0,2500.0]
extended_has_any_scalar_in_cmb_window	PASS	fraction=0.06583 (395/6000) in lin[2.0,2500.0]
extended_has_any_tensor_in_cmb_window	PASS	fraction=0.05783 (347/6000) in lin[2.0,2500.0]

Results (report.txt)

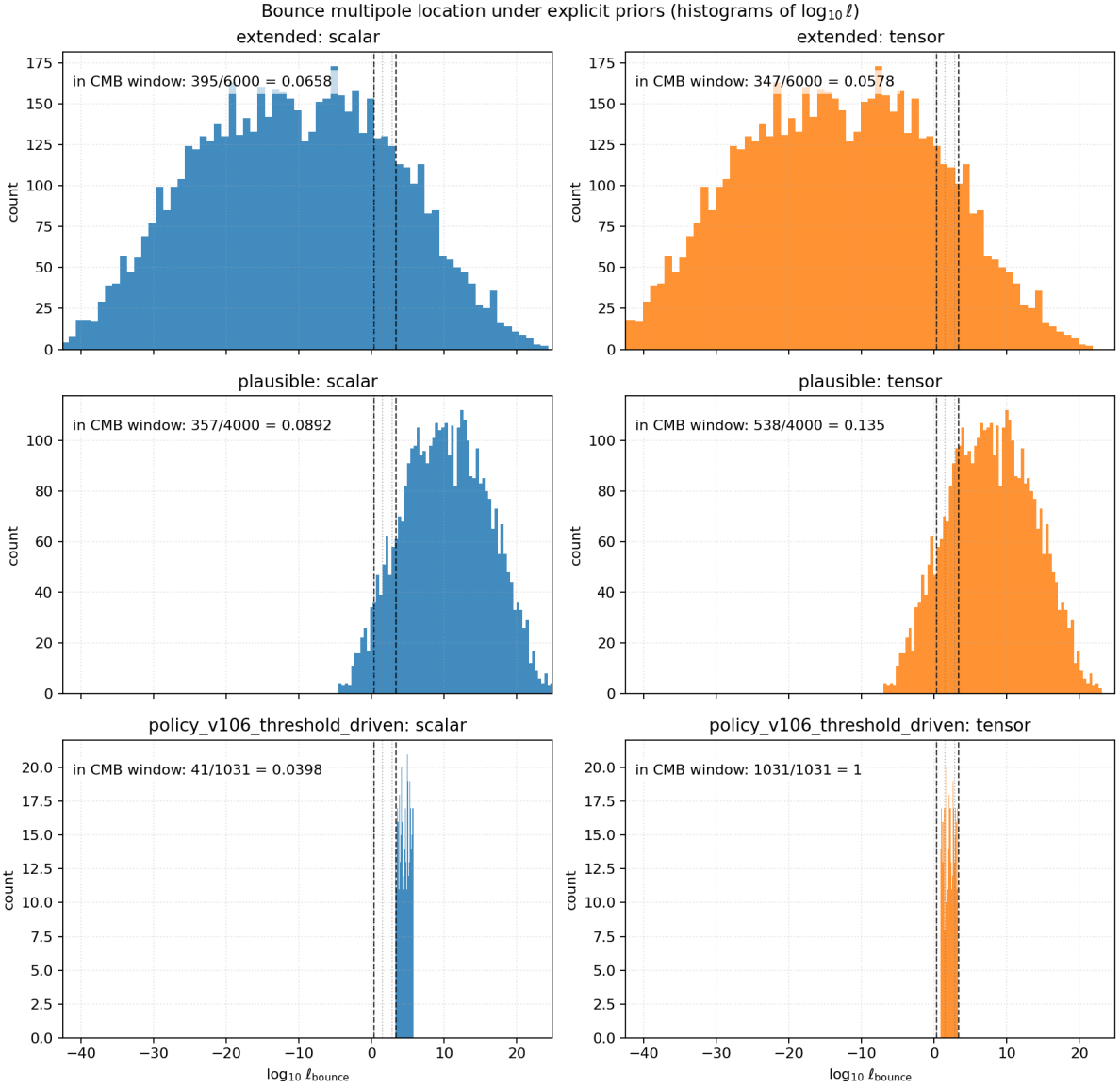
```
Unconventional: cosmology history sampler (k->l feasibility)

Purpose:
- Explore whether the bounce k-scale can plausibly map into CMB multipoles once an explicit a0/a_transition model is declared.
- This does *not* derive the expansion history; it quantifies feasibility under explicit priors.

Inputs:
- k_calibration config: tfpt-suite/tfpt_suite/data/k_calibration.json
- bounce diagnostics: live: tfpt-suite/out/bounce_perturbations/results.json
- k_bounce_s_raw=2103.55, k_bounce_t_raw=7.80804
- M = 3.060e+13 GeV (from TFPT M/Mpl and Mpl(reduced)=2.435e+18 GeV)
- chi_* = 13867.328 Mpc (flat LambdaCDM; H0=67.36, Omegam=0.3153, Omegar=9.2e-05, z*=1090.0)

Naive projection (no absolute normalization):
- l_bounce_s(naive) ~ 1.396e+59
- l_bounce_t(naive) ~ 5.180e+56

CMB window used for diagnostics: lin[2.0,2500.0]

Scenario: policy_v106_threshold_driven
- note: Threshold/policy-driven: N_pivot from n_s; N_reheat derived from T_reheat via rho scaling (v1.06 DeltaN model).
- priors: N_inflin(56.98005698005695, 56.98005698005695), N_rehin(0.0, 0.0), log10(Treh/GeV)in(-3.0, 15.0)
- kept_samples: 1031
- scalar in CMB window: 41/1031
- tensor in CMB window: 1031/1031
- log10 l quantiles (scalar): {'0.05': 3.42509124635, '0.5': 4.52979782008, '0.95': 5.63185076972}
- log10 l quantiles (tensor): {'0.05': 0.994680264804, '0.5': 2.09938683854, '0.95': 3.20143978818}

Scenario: plausible
- note: Conservative ranges around standard inflation+reheating expectations.

... (truncated, see report.txt for full output) ...
```

Plots

cosmo_history_sampler_cmb_fraction.png



`cosmo_history_sampler_log10ell.png`



C. Flavor Convention Search

Question: Which discrete flavor conventions perform best (with holdout)?

4. Unconventional: flavor holdout search (discrete CKM phase-map conventions)

Module ID: `ux_flavor_holdout_search` | **Output:** `tfpt-suite/out/unconventional/ux_flavor_holdout_search`

Objective

Purpose: This module implements the **?holdout principle?** from `tfpt-suite/unconventional/tasks.md` (Section C):

> search only over **discrete** convention choices, evaluate with a **holdout split**, and report both.

It is a safeguard against *silent convention shopping* in the flavor sector:

- if you allow yourself to try many discrete phase conventions, you can accidentally overfit the CKM table ?for free?.
- the holdout protocol forces you to keep some observables unseen during ranking.

Methodology

What it searches: A finite discrete grid of convention choices:

- `delta_source in {delta_star, tau_mu}`
- `s13_mode in {A_lam3_over_3, A_lam3_times_1_minus_delta}`
- `delta_mode in {pi_times_delta, pi_times_1_minus_delta, 2pi_times_delta, koide_pi_over_12}`

No continuous parameters are tuned.

Holdout split: - **Fit keys (7)**: `Vud, Vus, Vcd, Vcs, Vcb, Vts, Vtb`
- **Holdout keys (2)**: `Vub, Vtd`

Rationale: the smallest entries are most sensitive and easiest to ?convention-fix?.

Scale policy: Reference is labeled at \(M_Z\) in:

- `tfpt-suite/tfpt_suite/data/ckm_reference.json`

The module therefore runs:

- mt -> \(M_Z\) (short down-run) using `tfpt_suite/rge_pyrate_2loop.py`

This keeps the comparison at least *scale-aware* (still diagnostic; the reference is a low-energy fit snapshot, not a running MSbar parameter).

Checks

Check	Severity	Detail
evaluated_all_candidates	PASS	`candidates=16, rows=16`
best_candidate_has_finite_chi2	PASS	`best chi2_fit=2.475, chi2_holdout=185.887, total=188.362`
pmns_holdout_evaluated	PASS	`pmns_candidates=6 (from 6 permutation scan; best chi2_fit=3.159 chi2_holdout=13.257)`

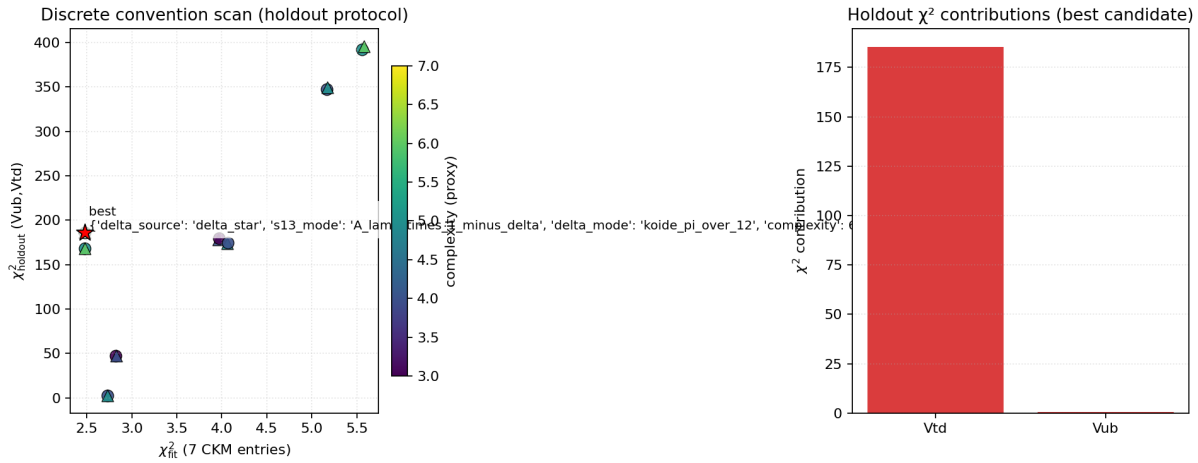
Results (report.txt)

```
Unconventional: flavor holdout search (discrete CKM conventions)

Holdout protocol:
- fit keys: ['Vud', 'Vus', 'Vcd', 'Vcs', 'Vcb', 'Vts', 'Vtb']
- holdout keys: ['Vub', 'Vtd']

Reference: tfpt-suite/tfpt_suite/data/ckm_reference.json (mu_ref=91.1876 GeV)
```

```
Boundary: mt=172.76 GeV; delta_M=0.607909; delta_star=0.608862

Top candidates (sorted by chi2_fit, then complexity, then chi2_holdout):
- {'delta_source': 'delta_star', 's13_mode': 'A_lam3_times_1_minus_delta', 'delta_mode': 'koide_pi_over_12',
 'complexity': 6}  chi2_fit=2.475  chi2_holdout=185.887  chi2_total=188.362  unitarity_dev=8.882e-16
- {'delta_source': 'tau_mu', 's13_mode': 'A_lam3_times_1_minus_delta', 'delta_mode': 'koide_pi_over_12',
 'complexity': 7}  chi2_fit=2.475  chi2_holdout=186.888  chi2_total=189.363  unitarity_dev=4.441e-16
- {'delta_source': 'delta_star', 's13_mode': 'A_lam3_over_3', 'delta_mode': 'koide_pi_over_12', 'complexity':
5}  chi2_fit=2.479  chi2_holdout=168.105  chi2_total=170.584  unitarity_dev=1.000e-15
- {'delta_source': 'tau_mu', 's13_mode': 'A_lam3_over_3', 'delta_mode': 'koide_pi_over_12', 'complexity':
6}  chi2_fit=2.479  chi2_holdout=168.105  chi2_total=170.585  unitarity_dev=1.998e-15
- {'delta_source': 'delta_star', 's13_mode': 'A_lam3_times_1_minus_delta', 'delta_mode': 'pi_times_1_minus_delta',
 'complexity': 4}  chi2_fit=2.727  chi2_holdout=2.378  chi2_total=5.106  unitarity_dev=8.882e-16
- {'delta_source': 'tau_mu', 's13_mode': 'A_lam3_times_1_minus_delta', 'delta_mode': 'pi_times_1_minus_delta',
 'complexity': 5}  chi2_fit=2.729  chi2_holdout=2.399  chi2_total=5.129  unitarity_dev=7.434e-16
- {'delta_source': 'delta_star', 's13_mode': 'A_lam3_over_3', 'delta_mode': 'pi_times_1_minus_delta',
 'complexity': 3}  chi2_fit=2.822  chi2_holdout=47.518  chi2_total=50.340  unitarity_dev=8.882e-16
- {'delta_source': 'tau_mu', 's13_mode': 'A_lam3_over_3', 'delta_mode': 'pi_times_1_minus_delta', 'complexity':
4}  chi2_fit=2.825  chi2_holdout=47.644  chi2_total=50.469  unitarity_dev=8.882e-16

Best candidate details (per-entry contributions):
- candidate: {'delta_source': 'delta_star', 's13_mode': 'A_lam3_times_1_minus_delta', 'delta_mode': 'koide_pi_over_12', 'complex
y': 6}
- contrib_fit_top: [{'key': 'Vus', 'pred': 0.224457808373, 'mean': 0.22501, 'sigma': 0.00068, 'chi2': 0.659419536004}, {'key': 'V
d', 'pred': 0.974476919441, 'mean': 0.97435, 'sigma': 0.00016, 'chi2': 0.629240023616}, {'key': 'Vcs', 'pred': 0.973601238184, 'm
an': 0.97349, 'sigma': 0.00016, 'chi2': 0.483356779316}, {'key': 'Vcd', 'pred': 0.224407690306, 'mean': 0.22487, 'sigma': 0.0006
 'chi2': 0.462219405545}, {'key': 'Vts', 'pred': 0.0414646990516, 'mean': 0.04111, 'sigma': 0.00077, 'chi2': 0.212196689473}]
- contrib_holdout: [{'key': 'Vtd', 'pred': 0.00599349710197, 'mean': 0.00858, 'sigma': 0.00019, 'chi2': 185.31848314504813}, {'k
': 'Vub', 'pred': 0.00366411470972, 'mean': 0.003732, 'sigma': 9e-05, 'chi2': 0.56893983169}]

PMNS holdout (new; avoids silent deltaCP convention shopping):
- reference: tfpt-suite/tfpt_suite/data/pmns_reference.json
- fit keys: sin2_theta12,sin2_theta13,sin2_theta23; holdout key: delta_cp_deg
- status: OK
- best PMNS candidate: {'perm': [0, 1, 2], 'ordering': 'normal', 'complexity': 0, 'angles_deg': {'delta_cp_deg': 90.0000000000003
, 'theta12_deg': 34.3225259039, 'theta13_deg': 8.74369300841, 'theta23_deg': 42.46122629316272}, 'chi2_fit': 3.15900082137935, 'c
i2_holdout': 13.2570677186, 'chi2_total': 16.41606853998547, 'contrib_fit': [{'key': 'sin2_theta12', 'pred': 0.317927709894, 'mea
': 0.307, 'sigma': 0.012, 'chi2': 0.82926974673}, {'key': 'sin2_theta13', 'pred': 0.0231084351589, 'mean': 0.02224, 'sigma': 0.00
57, 'chi2': 2.32126692884}, {'key': 'sin2_theta23', 'pred': 0.455748015056, 'mean': 0.454, 'sigma': 0.019, 'chi2': 0.00846414580
1}], 'contrib_holdout': [{'key': 'delta_cp_deg', 'pred': 90.00000000000031, 'mean': 232.0, 'sigma': 39.0, 'chi2': 13.2570677186}

Checks:
- evaluated_all_candidates: PASS (candidates=16, rows=16)
- best_candidate_has_finite_chi2: PASS (best chi2_fit=2.475, chi2_holdout=185.887, total=188.362)
- pmns_holdout_evaluated: PASS (pmns_candidates=6 (from 6 permutation scan; best chi2_fit=3.159 chi2_holdout=13.257))

Notes:
- This module is diagnostic. It does not claim an operator-level topology->phase derivation.
- It enforces a holdout split to reduce the risk of 'convention shopping' that overfits the full CKM table.
- PMNS holdout is implemented as a best-effort scan over the discrete PMNS permutation conventions emitted by pmns_full_pipeline
```

Plots

flavor_holdout.png



D. Gravity Gauge-Fixing

Question: Which gauge-fixing choice minimizes non-minimal operator structure?

5. Unconventional: gravitation gauge-fixing GA (toy nonminimal -> Laplace-type)

Module ID: `ux_gravity_gaugefix_ga` | **Output:** `tfpt-suite/out/unconventional/ux_gravity_gaugefix_ga`

Objective

Purpose: This module implements the **?GA search scaffold?** described in `tfpt-suite/unconventional/tasks.md` (Section A).

It searches (in a **toy operator family**) for gauge-fixing choices that make the quadratic operator **Laplace-type** (minimal), i.e. remove nonminimal \(\nabla_\mu\nabla_\nu\) structure.

What it is (and is not): - **It is**: a deterministic genetic-algorithm harness over a small discrete+continuous genome that minimizes a *structural nonminimality measure*.
- **It is not**: the publication-grade BRST derivation of the torsion-sector quadratic operator from the microscopic action. That remains the real ToE gap.

Methodology

Toy model used: We model a vector-type quadratic operator as:

\[
\Delta_{\mu\nu} = -g_{\mu\nu}\Box + c_{\mathrm{nonmin}}\,\nabla_\mu\nabla_\nu + E\,g_{\mu\nu}.
\]

The module uses a toy parameterization:

\[
c_{\mathrm{nonmin}} = 1 - \gamma/\xi,
\]

with:

- \(\xi>0\): gauge parameter
- \(\gamma\): discrete normalization choice of the gauge-fixing functional

Laplace-type is achieved when \(c_{\mathrm{nonmin}}=0\), i.e. \(\xi=\gamma\).

This is the minimal place where a GA is useful: as soon as you have a real operator family with many discrete choices, you want a deterministic search layer that optimizes **structure** (not experimental fit).

Outputs: The module reports:

- best genome (family, \(\gamma\), \(\xi\))
- best nonminimal coefficient \(c_{\mathrm{nonmin}}\)
- a small top-10 snapshot of the final GA population
- ?docking context? info about `effective_action_r2_operator_spec.json` (for narrative continuity)

Checks

Check	Severity	Detail
ga_found_laplace_type_candidate	PASS	`best |c_nonmin|=0.000e+00 with genome=GaugeFixingGenome(family='lorenz', gamma=1.0, xi=1.0)`
ga_best_close_to_analytic_optimum	PASS	`analytic optimum in chosen family: xi*=gamma=1.0 gives c_nonmin=0.000e+00`

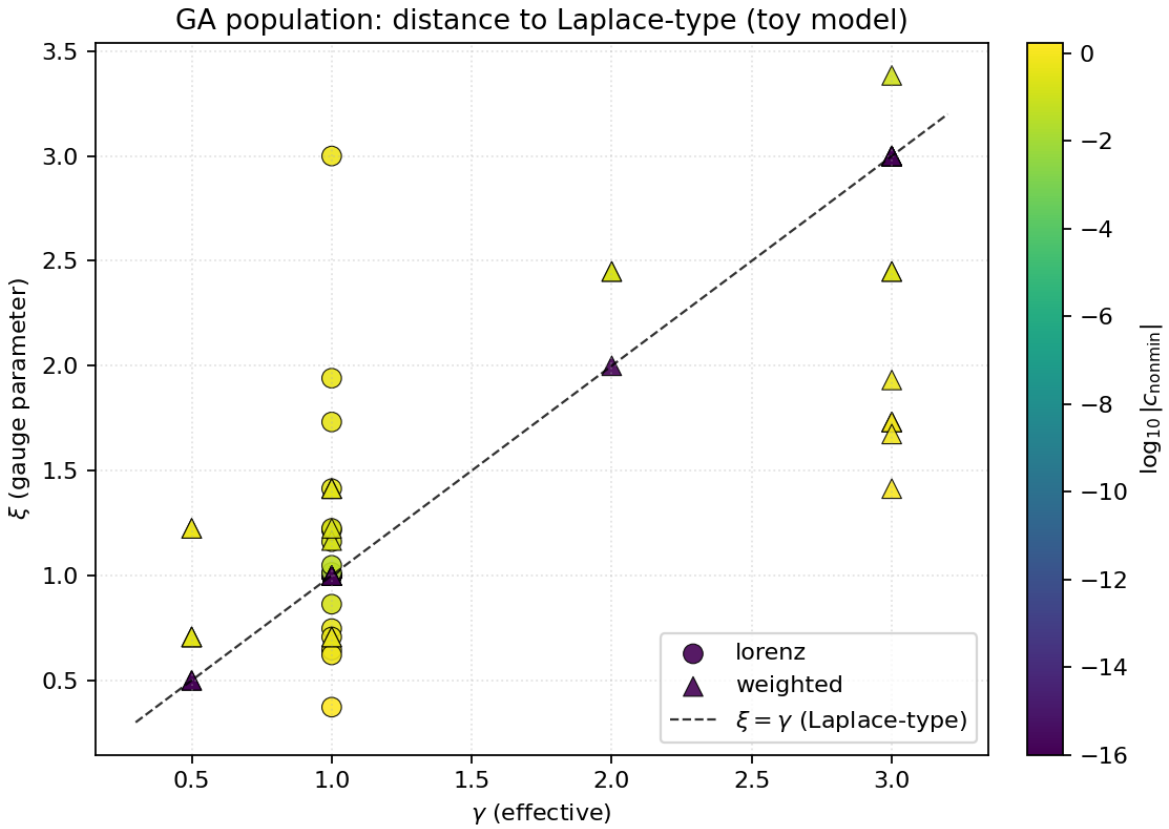
Check	Severity	Detail
discrete_closed_form_optimum_is_laplace_type	PASS	best discrete candidate=GaugeFixingGenome(family='lorenz', gamma=1.0, xi=1.0) with c_nonmin=0.0
effective_action_r2_operator_spec_present	PASS	path=/Users/stefanhamann/Projekte/wolfram_latex_attachments/tfpt-suite/tfpt_suite/data/effective_action_r2_operator_spec.json

Results (report.txt)

```
Unconventional: gravitation gauge-fixing GA (toy model)

Goal:
- Demonstrate the *search scaffold* for finding a gauge-fixing choice that yields a Laplace-type (minimal) operator.
- This is NOT the missing BRST-grade derivation from the microscopic torsionful action.

Toy operator:
- Delta_{munu} = -g_{munu} [] + c_nonmin nabla_munabla_nu + E g_{munu}
- c_nonmin = 1 - gamma/xi  (gamma is a discrete normalization choice; xi is the gauge parameter)
- Laplace-type when c_nonmin = 0 (=> xi = gamma).

GA result:
- best genome: family=lorenz, gamma=1.0, xi=1.0
- best nonminimal coefficient: c_nonmin=0.000000000000e+00

Analytic comparison (same family):
- xi* = gamma = 1.0 => c_nonmin(xi*) = 0.000000000000e+00

Best discrete closed-form option (over families * gamma):
- Candidate(genome=GaugeFixingGenome(family='lorenz', gamma=1.0, xi=1.0), nonminimal_coeff=0.0, score=0.0)

OperatorSpec docking context (effective_action_r2):
- file: tfpt-suite/tfpt_suite/data/effective_action_r2_operator_spec.json
- note: OperatorSpec for effective_action_r2 on a 4D constant-curvature background. This file is generated deterministically fro
the canonical microscopic action spec (tfpt_suite/data/microscopic_action_tfpt_v25.json) using the K4 closure equation for the m
imal Laplace-type torsion+ghost block operator.
- blocks in spec: 4

Top-10 GA population snapshot:
- {'family': 'lorenz', 'gamma': 1.0, 'xi': 1.0, 'c_nonmin': 0.0, 'score': 0.0}
- {'family': 'weighted', 'gamma': 0.5, 'xi': 0.5, 'c_nonmin': 0.0, 'score': 0.0}
- {'family': 'weighted', 'gamma': 1.0, 'xi': 1.0, 'c_nonmin': 0.0, 'score': 0.0}

... (truncated, see report.txt for full output) ...
```

Plots

gravity_gaugefix_ga.png


GA population: distance to Laplace-type (toy model)
ξ (gauge parameter)
γ (effective)
log10 |cnonmin|
lorenz
weighted
ξ = γ (Laplace-type)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.5
1.0
1.5
2.0
2.5
3.0
0
−2
−4
−6
−8
−10
−12
−14
−16

E. Omegab-APS Bridge

Question: Can the APS seam term explain the Omegab coefficient?

6. Unconventional: Omega_b coefficient bridge via APS seam term (DeltaGamma)

Module ID: `ux_omega_b_aps_bridge` | **Output:** `tfpt-suite/out/unconventional/ux_omega_b_aps_bridge`

Objective

Purpose: The main suite currently contains an explicitly **conditional** Omega_b identity module:

- `tfpt_suite/modules/omega_b_conjecture_scan.py`

There, the coefficient \(4\pi-1\) is justified via a **sector-counting assumptions block**.

This unconventional module provides a more ?docked? candidate bridge:

> express \(4\pi-1\) as a function of an already-computed *topological seam quantity* in the suite.

Concretely it uses the APS seam toy model:

- `tfpt_suite/modules/aps_eta_gluing.py`

and its seam term:

\[
\Delta_\Gamma := 2\pi \cdot \mathrm{SF}(U_\Gamma)
\]

For the minimal nontrivial class \(m=1\), the suite computes \(\mathrm{SF}=1\) and hence \(\Delta_\Gamma=2\pi\).

Then the coefficient becomes:

\[
K_{\mathrm{candidate}} := 2\Delta_\Gamma - 1 = 4\pi - 1.
\]

Why this matters for ?ToE closure?: In `tfpt-suite/progress.md`, Omega_b is flagged as:

- implemented as a conditional identity
- still missing an **operator/anomaly-level derivation** (inflow / index / eta-gluing logic)

This module does **not** claim to finish that derivation. What it does provide is a concrete docking point:

- Omega_b coefficient <-> APS seam term \(\Delta_\Gamma\)

That makes it much clearer what a future anomaly/inflow calculation would have to reproduce.

Methodology

What the module computes: - Recomputes the APS seam spectral flow for \(m=1\) (periodic spin) using the same toy model as `aps_eta_gluing`.
- Forms \(K_{\mathrm{candidate}} = 2\Delta_\Gamma - 1\).
- Computes:
- \(\Omega_b^{\mathrm{pred}} = K_{\mathrm{candidate}} \beta_{\mathrm{rad}}\)
- Planck-derived reference Omega_b and the implied coefficient \(K := \Omega_b/\beta_{\mathrm{rad}}\)
- a diagnostic z-score (agreement indicator, not a proof)
- Emits an explicit assumptions list; the key bridge step remains **conditional**.

Checks

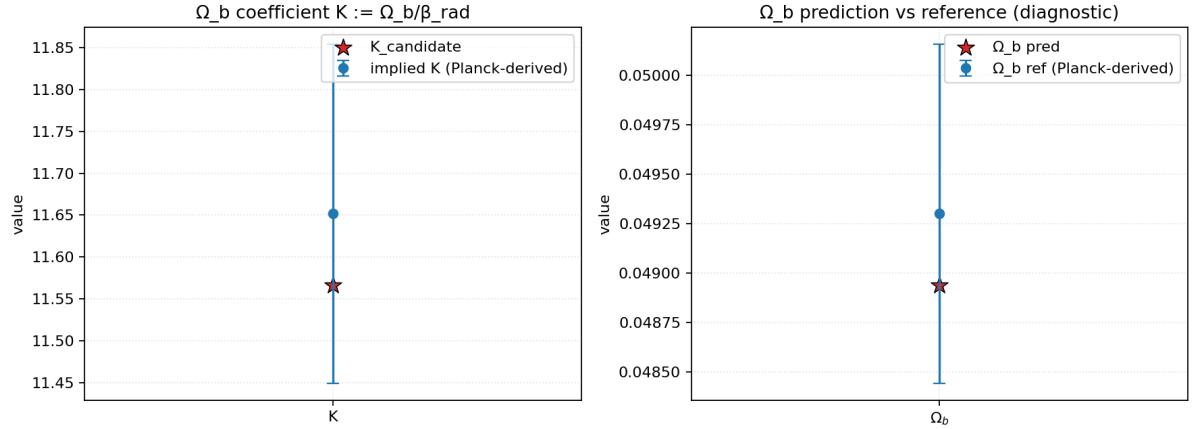
Check	Severity	Detail
aps_spectral_flow_m1	PASS	m=1 periodic: numeric_sf=1, winding=1
delta_gamma_equals_2pi	PASS	DeltaGamma=2pi*SF with SF=1 => DeltaGamma=6.28318530718
K_candidate_equals_4pi_minus_1	PASS	K_candidate=2DeltaGamma-1=11.5663706144 (vs 4pi-1)
omega_b_pred_positive	PASS	Omega_b_pred=0.0489406626655
omega_b_pred_close_to_planck_ref_diagnostic	PASS	Omega_b_ref=0.0493016923285 +/- 8.568114e-04; z=0.421364201619

Results (report.txt)

```
Unconventional: Omega_b bridge via APS seam term

Idea:
- Replace a raw (4pi-1) insertion by a quantity already computed in-suite: the APS seam term DeltaGamma.
- This remains conditional until an operator/anomaly-level derivation connects Omega_b to DeltaGamma.

APS seam toy-model (periodic spin):
- epsilon = 0.001
- m = 1 => SF(U_Gamma) = 1 (analytic=1), winding(det U_Gamma) = 1
- DeltaGamma := 2pi*SF = 6.28318530718

Bridge conjecture (conditional):
- K_candidate := 2*DeltaGamma - 1 = 11.5663706144
- beta_rad = varphi0/(4pi) = 0.0042312895114
- Omega_b_pred := K_candidate*beta_rad = 0.0489406626655

Reference (Planck 2018 base-LambdaCDM; derived Omega_b):
- Omega_b h^2 = 0.02237 +/- 0.00015
- H0 = 67.36 +/- 0.54 km/s/Mpc => h=0.6736 +/- 0.0054
- Omega_b_ref = Omega_b h^2 / h^2 = 0.0493016923285 +/- 8.568114e-04
- implied K = Omega_b_ref / beta_rad = 11.6516944056 +/- 0.20249416287
- |K_candidate - implied K| = 0.0853237912703 (diagnostic)

Assumptions (explicit):
- aps_seam_term_toy_model: Use the 1D Dirac-family toy model of the seam operator (Appendix seam) where
DeltaGamma := 2pi*SF(U_Gamma) for U_Gamma(theta)=exp(i m theta).  [implemented (see aps_eta_gluing)]
- minimal_nontrivial_class_m_eq_1: Use the minimal nontrivial winding class m=1 (so SF=1 in the toy model).
 [checked in aps_eta_gluing (minimal m with SF>0 is 1)]
- omega_b_coeff_equals_2_delta_gamma_minus_1: Bridge postulate: the baryon coefficient K := Omega_b/beta_rad
equals (2*DeltaGamma - 1) in the same normalization.  [conditional / to be replaced by an operator/anomaly-level
derivation]

Checks:
- aps_spectral_flow_m1: PASS (m=1 periodic: numeric_sf=1, winding=1)
- delta_gamma_equals_2pi: PASS (DeltaGamma=2pi*SF with SF=1 => DeltaGamma=6.28318530718)
- K_candidate_equals_4pi_minus_1: PASS (K_candidate=2DeltaGamma-1=11.5663706144 (vs 4pi-1))
- omega_b_pred_positive: PASS (Omega_b_pred=0.0489406626655)
- omega_b_pred_close_to_planck_ref_diagnostic: PASS (Omega_b_ref=0.0493016923285 +/- 8.568114e-04; z=0.421364201619)

Notes:
- This module is intentionally conservative: it does not claim an operator-level Omega_b derivation.
- It provides a concrete *docking point*: Omega_b coefficient <-> DeltaGamma (APS seam), which can be upgraded to an anomaly/inf
w computation later.
```

Plots

omega_b_aps_bridge.png



F. Torsion Regime Design

Question: Which physical regimes could make TFPT torsion falsifiable?

7. Unconventional: torsion regime designer (spin-polarized medium + bound saturation targets)

Module ID: `ux_torsion_regime_designer` | **Output:** `tfpt-suite/out/unconventional/ux_torsion_regime_designer`

Objective

Purpose: `tfpt-suite/progress.md` flags torsion falsifiability as a ToE closure gap:

- the suite has a vetted bounds ingestion (`torsion_bounds_mapping`)
- but the ?today torsion? prediction is still a **toy regime**
- what?s missing is a **nontrivial, computable present-day regime** (spin-polarized matter / magnetars / plasma)

This module is an *unconventional design tool* to propose such regimes in a way that is:

- explicit about assumptions
- directly comparable to vetted bounds
- compatible with the existing `torsion_bounds_mapping` regime evaluation

Methodology

Toy model used (explicit, not derived): The module uses a minimal spin-medium proxy:

$$
|S_\mu| \sim c_{\rm spin}\;\frac{\rho_{\rm spin}}{M_{\rm eff}^2},
\qquad
\rho_{\rm spin} \equiv (\text{polarization})\cdot(\text{spin\_per\_particle})\cdot n
$$

where:

- n is a number density (converted to GeV^3)
- $M_{\rm eff}$ is either:
- `Mpl_reduced` (very conservative), or
- `TFPT_M` (uses the TFPT Starobinsky scale M)
- $c_{\rm spin}$ is a dimensionless factor (not derived here)

The key design output is:

$$
c_{\rm spin,max} := \frac{|S_\mu|_{\rm bound}}{|S_\mu|_{\rm pred}(c_{\rm spin}=1)},
$$

so you can see **how much suppression** is required to stay within bounds for a given physical scenario.

Outputs: - tightest vetted component-wise bound (from `torsion_bounds_vetted.json`)
- a few ?anchor scenarios? (lab matter, nuclear matter)
- random scenario exploration to find interesting candidates
- a simple **observable proxy** per scenario: $\Delta\nu \approx 2|b|\cdot(\mathrm{GeV}\to\mathrm{Hz})$ with $|b|\approx(3/4)|S|$ (design-phase; not a full experiment model)
- **ready-to-copy JSON regime proposals** compatible with `tfpt_suite/data/torsion_regimes.json`

Checks

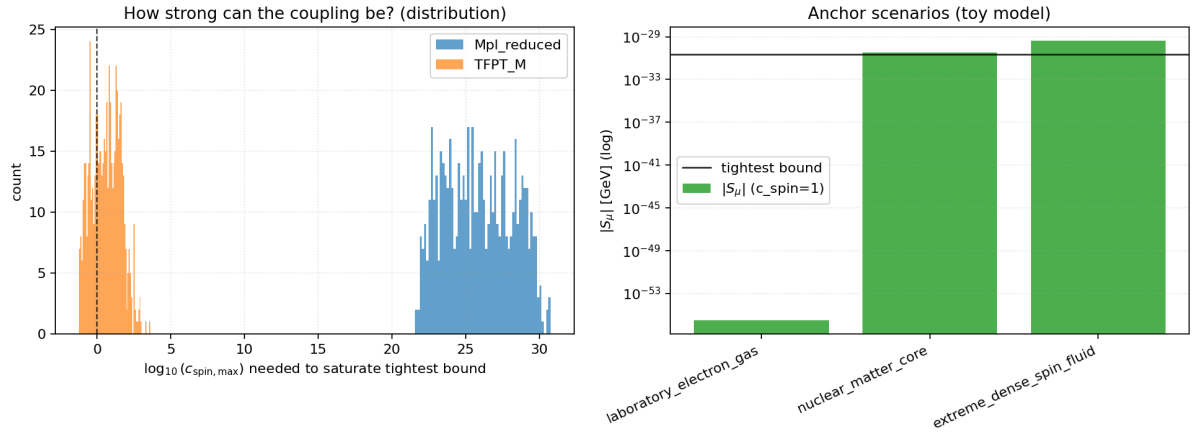
Check	Severity	Detail
vetted_bounds_loaded	PASS	bounds=4; tightest=A_X:2.100e-31 GeV
proposals_generated	PASS	proposals=2 (compatible with torsion_regimes.json schema)

Results (report.txt)

```
Unconventional: torsion regime designer

Purpose:
- Provide concrete, nontrivial candidate regimes for present-day torsion falsifiability.
- Make explicit what suppression/normalization factor c_spin would be required to saturate vetted bounds.

Bounds file: tfpt-suite/tfpt_suite/data/torsion_bounds_vetted.json
Tightest component-wise bound: A_X (component=X) <= 2.100e-31 GeV

Toy model used (explicit; not derived here):
- |S_mu| ~ c_spin * (polarization * spin_per_particle * n) / M_eff^2
- observable proxy: Deltanu ~ 2|b|*(GeV->Hz), with |b|~(3/4)|S| and GeV->Hz=2.418e+23
- coupling_kind=Mpl_reduced uses M_eff = Mpl(reduced)
- coupling_kind=TFPT_M uses M_eff = TFPT M scale (from effective_action_r2 / constants)

Named anchor scenarios (c_spin=1):
- {'label': 'laboratory_electron_gas', 'coupling_kind': 'Mpl_reduced', 'n_value': 1e+23, 'n_unit': 'cm^-3', 'polarization': 0.5,
spin_per_particle': 0.5, 'S_mu_pred_cspin_1_GeV': 3.2396753580225e-56, 'delta_nu_Hz_cspin_1': 1.17502502449e-32, 'c_spin_max_to_
turate_tightest_bound': 6.48213097896e+24}
- {'label': 'nuclear_matter_core', 'coupling_kind': 'TFPT_M', 'n_value': 0.16, 'n_unit': 'fm^-3', 'polarization': 0.5, 'spin_per
article': 0.5, 'S_mu_pred_cspin_1_GeV': 3.28322384301e-31, 'delta_nu_Hz_cspin_1': 1.19081998972e-07, 'c_spin_max_to_saturate_tig
est_bound': 0.639615238075}
- {'label': 'extreme_dense_spin_fluid', 'coupling_kind': 'TFPT_M', 'n_value': 1.0, 'n_unit': 'fm^-3', 'polarization': 1.0, 'spin
er_particle': 0.5, 'S_mu_pred_cspin_1_GeV': 4.10402980376e-30, 'delta_nu_Hz_cspin_1': 1.48852498715e-06, 'c_spin_max_to_saturate
ightest_bound': 0.051169219046}

Proposed regime JSON entries (copy into tfpt_suite/data/torsion_regimes.json if desired):
{
  "c_spin": 1.0,
  "compare_to_bounds": true,
  "coupling_scale": {
    "kind": "Mpl_reduced"
  },
  "id": "spin_medium_candidate_1",
  "label": "Spin-polarized medium candidate 1 (Mpl_reduced)",
  "model": "spin_polarized_medium",

... (truncated, see report.txt for full output) ...
```

Plots

torsion_regime_designer.png



Appendix: JSON Data

Complete results.json per module for machine processing.

ux_cosmo_history_sampler


```
{
  "checks": [
    {
      "check_id": "bounce_source_resolved",
      "detail": "bounce_source=live: tfpt-suite/out/bounce_perturbations/results.json; k_bounce_s_raw=2103.5507357951246; k_boun
_t_raw=7.80803964429",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "chi_star_computed",
      "detail": "chi_star(z*=1090.0)=13867.328 Mpc (flat \u039bCDM)",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "naive_ell_is_huge_as_expected",
      "detail": "ell_naive scalar=1.396e+59, tensor=5.180e+56",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "policy_v106_threshold_driven_has_any_scalar_in_cmb_window",
      "detail": "fraction=0.03977 (41/1031) in \u2113\u2208[2.0,2500.0]",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "policy_v106_threshold_driven_has_any_tensor_in_cmb_window",
      "detail": "fraction=1 (1031/1031) in \u2113\u2208[2.0,2500.0]",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "plausible_has_any_scalar_in_cmb_window",
      "detail": "fraction=0.08925 (357/4000) in \u2113\u2208[2.0,2500.0]",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "plausible_has_any_tensor_in_cmb_window",
      "detail": "fraction=0.1345 (538/4000) in \u2113\u2208[2.0,2500.0]",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "extended_has_any_scalar_in_cmb_window",
      "detail": "fraction=0.06583 (395/6000) in \u2113\u2208[2.0,2500.0]",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "extended_has_any_tensor_in_cmb_window",
      "detail": "fraction=0.05783 (347/6000) in \u2113\u2208[2.0,2500.0]",
      "passed": true,
      "severity": null
    }
  ],
  "module_id": "ux_cosmo_history_sampler",
  "plot": {
    "cosmo_history_sampler_cmb_fraction_png": "tfpt-suite/out/unconventional/ux_cosmo_history_sampler/cosmo_history_sampler_cmb_
action.png",
    "cosmo_history_sampler_log10ell_png": "tfpt-suite/out/unconventional/ux_cosmo_history_sampler/cosmo_history_sampler_log10ell
ng"
  },
  "results": {
    "bounce": {
      "k_bounce_s_raw": 2103.5507357951246,
      "k_bounce_t_raw": 7.80803964429
    },
    "bounce_source": "live: tfpt-suite/out/bounce_perturbations/results.json",
    "config_file": "tfpt-suite/tfpt_suite/data/k_calibration.json",
    "constants": {
      "GeV_to_Mpc_inv": 1.56373830646e+38,
      "M_GeV": 30595633972661.273,
      "M_over_Mpl": "1.256494e-05",
```

```
      "Mpl_reduced_GeV": 2.435e+18
    },
    "cosmology": {
      "H0_km_s_Mpc": 67.36,
      "Omega_m": 0.3153,
      "Omega_r": 9.2e-05,
      "chi_star_Mpc": 13867.328294431452,
      "z_star": 1090.0
    },
    "diagnostics": {
      "cmb_window": {
        "max": 2500.0,
        "min": 2.0
      },
      "ell_targets": [
        2.0,
        30.0,
        700.0
      ],
      "transition": "horizon_exit_of_pivot"
    },
    "naive": {
      "ell_bounce_s": 1.39562686302e+59,
      "ell_bounce_t": 5.18034088253e+56
    },
    "plot": {
      "cosmo_history_sampler_cmb_fraction_png": "tfpt-suite/out/unconventional/ux_cosmo_history_sampler/cosmo_history_sampler_cmb
fraction.png",
      "cosmo_history_sampler_log10ell_png": "tfpt-suite/out/unconventional/ux_cosmo_history_sampler/cosmo_history_sampler_log10e
.png"
    },
    "scenarios": [
      {
        "best_candidates": [
          {
            "abs_log10_error": 2.98052727538,
            "ell_bounce": 1912.3054864807511,
            "params": {
              "N_inflation_from_transition": 56.98005698005695,
              "N_reheat": 23.9817264907,
              "T_reheat_GeV": 37766536.22667426,
              "a0_over_a_transition": 7.29813762962e+55
            },
            "sector": "scalar",
            "target_ell": 2.0
          },
          {
            "abs_log10_error": 1.80443601632,
            "ell_bounce": 1912.3054864807511,
            "params": {
              "N_inflation_from_transition": 56.98005698005695,
              "N_reheat": 23.9817264907,
              "T_reheat_GeV": 37766536.22667426,
              "a0_over_a_transition": 7.29813762962e+55
            },
            "sector": "scalar",
            "target_ell": 30.0
          },
          {
            "abs_log10_error": 0.43645923103,
            "ell_bounce": 1912.3054864807511,
            "params": {
              "N_inflation_from_transition": 56.98005698005695,
              "N_reheat": 23.9817264907,
              "T_reheat_GeV": 37766536.22667426,
              "a0_over_a_transition": 7.29813762962e+55
            },
            "sector": "scalar",
            "target_ell": 700.0
          },
          {
            "abs_log10_error": 0.550116293837,
            "ell_bounce": 7.09816825255,
            "params": {
              "N_inflation_from_transition": 56.98005698005695,
              "N_reheat": 23.9817264907,
              "T_reheat_GeV": 37766536.22667426,
              "a0_over_a_transition": 7.29813762962e+55
            },
            "sector": "tensor",
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            "abs_log10_error": 7.039923e-04,
            "ell_bounce": 29.9514093249,
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            "params": {
              "N_inflation_from_transition": 56.98005698005695,
              "N_reheat": 18.2227680058,
              "T_reheat_GeV": 2837396794.566826,
              "a0_over_a_transition": 1.72958167889e+55
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            "sector": "tensor",
            "target_ell": 30.0
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          {
            "abs_log10_error": 2.143916e-04,
            "ell_bounce": 700.3456437042189,
            "params": {
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              "N_reheat": 5.61477756372,
              "T_reheat_GeV": 36274846338949.73,
              "a0_over_a_transition": 7.39683459032e+53
            },
            "sector": "tensor",
            "target_ell": 700.0
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        "cmb_window": {
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        "counts": {
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          "scalar_total": 1031,
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          "tensor_total": 1031
        },
        "ell_minmax": {
          "scalar": {
            "max": 569207.9391249071,
            "min": 1912.3054864807511
          },
          "tensor": {
            "max": 2112.807682223431,
            "min": 7.09816825255
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        },
        "kept_samples": 1031,
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            "0.05": 3.42509124635,
            "0.5": 4.52979782008,
            "0.95": 5.63185076972
          },
          "tensor": {
            "0.05": 0.994680264804,
            "0.5": 2.09938683854,
            "0.95": 3.20143978818
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        },
        "scenario": {
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            56.98005698005695
          ],
          "N_reheat_range": [
            0.0,
            0.0
          ],
          "id": "policy_v106_threshold_driven",
          "log10_T_reheat_GeV_range": [
            -3.0,
            15.0
          ],
          "note": "Threshold/policy-driven: N_pivot from n_s; N_reheat derived from T_reheat via \u03c1 scaling (v1.06 \u0394N m
el).",
          "samples": 2500
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      },
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            "abs_log10_error": 0.0146106638135,
            "ell_bounce": 2.06842919715,
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              "N_reheat": 10.4492581093,
              "T_reheat_GeV": 22536297918772.934,
              "a0_over_a_transition": 6.74727887686e+58
            },
```

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      "sector": "scalar",
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    {
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        "N_reheat": 13.2781369895,
        "T_reheat_GeV": 1674410481.4848073,
        "a0_over_a_transition": 4.67073017217e+57
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      "sector": "scalar",
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      "abs_log10_error": 0.0032412180685,
      "ell_bounce": 694.7952199791922,
      "params": {
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        "N_reheat": 1.3960439107,
        "T_reheat_GeV": 313437233043942.56,
        "a0_over_a_transition": 2.00868806073e+56
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      "sector": "scalar",
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        "N_reheat": 11.2006315743,
        "T_reheat_GeV": 1742429471781.9526,
        "a0_over_a_transition": 2.62400585143e+56
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      "sector": "tensor",
      "target_ell": 2.0
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      "abs_log10_error": 0.00254861677852,
      "ell_bounce": 30.17656979504113,
      "params": {
        "N_inflation_from_transition": 66.2082683599951,
        "N_reheat": 12.6309728643,
        "T_reheat_GeV": 74197958.87807138,
        "a0_over_a_transition": 1.71667652013e+55
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      "sector": "tensor",
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      "abs_log10_error": 8.952451e-04,
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        "N_reheat": 2.38776483312,
        "T_reheat_GeV": 6967623880575.59,
        "a0_over_a_transition": 7.41575791021e+53
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      "sector": "tensor",
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  "cmb_window": {
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    "scalar_total": 4000,
    "tensor_in_cmb": 538,
    "tensor_total": 4000
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  "ell_minmax": {
    "scalar": {
      "max": 3.24208702228e+25,
      "min": 2.92868575023e-05
    },
    "tensor": {
      "max": 1.20341019446e+23,
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  "kept_samples": 4000,
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  "log10_ell_quantiles": {
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      "0.5": 10.1753044921,
      "0.95": 19.7871304711
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    "tensor": {
      "0.05": -1.74055806062,
      "0.5": 7.7448935106,
      "0.95": 17.3567194895
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  },
  "scenario": {
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    "N_reheat_range": [
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      15.0
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    "id": "plausible",
    "log10_T_reheat_GeV_range": [
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    ],
    "note": "Conservative ranges around standard inflation+reheating expectations.",
    "samples": 4000
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{
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        "T_reheat_GeV": 7072036099024.191,
        "a0_over_a_transition": 6.99152693503737e+58
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      "ell_bounce": 29.9390351393,
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        "N_reheat": 24.2570821247,
        "T_reheat_GeV": 2824170.5570849394,
        "a0_over_a_transition": 4.66156259388e+57
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      "sector": "scalar",
      "target_ell": 30.0
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        "N_reheat": 4.48356040429,
        "T_reheat_GeV": 33130012.895092145,
        "a0_over_a_transition": 1.98508065011e+56
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        "T_reheat_GeV": 1254496406.7651157,
        "a0_over_a_transition": 2.54399785237e+56
      },
      "sector": "tensor",
      "target_ell": 2.0
    },
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      "ell_bounce": 30.05740599660897,
      "params": {
        "N_inflation_from_transition": 68.17779295385552,
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            "N_reheat": 0.20378227625,
            "T_reheat_GeV": 2593086279254.968,
            "a0_over_a_transition": 1.72348235344e+55
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          "sector": "tensor",
          "target_ell": 30.0
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            "N_reheat": 1.32585715352,
            "T_reheat_GeV": 7136314963189.277,
            "a0_over_a_transition": 7.40250235877e+53
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        "scalar_total": 6000,
        "tensor_in_cmb": 347,
        "tensor_total": 6000
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        "scalar": {
          "max": 2.04065924243e+24,
          "min": 2.08799384152e-46
        },
        "tensor": {
          "max": 7.5745966067e+21,
          "min": 7.7502949723e-49
        }
      },
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          "0.5": -10.606254335,
          "0.95": 11.0965086628
        },
        "tensor": {
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          "0.5": -13.0366653166,
          "0.95": 8.66609768122
        }
      },
      "scenario": {
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          140.0
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        "N_reheat_range": [
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          40.0
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        "id": "extended",
        "log10_T_reheat_GeV_range": [
          -2.0,
          15.0
        ],
        "note": "Extended ranges to test whether CMB visibility requires extreme expansion budgets.",
        "samples": 6000
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    }
  ]
},
"schema_version": 1,
"spec": {
  "assumptions": [],
  "determinism": "Deterministic given config seed + precision.",
  "formulas": [
    "a0/a_transition = (a0/a_reh) * exp(N_reheat) * exp(N_inflation_from_transition)",
    "a0/a_reh from entropy conservation (instantaneous reheating)",
    "\u2113 \u2248 k(Mpc^{-1}) \u00b7 \u03c7_*;  k(Mpc^{-1}) = k_hat * M_GeV * (GeV\u2192Mpc^{-1}) / (a0/a_transition)"
  ],
  "gaps": [],
  "inputs": [
    "bounce diagnostics: prefer tfpt-suite/out/bounce_perturbations/results.json; else fallback in tfpt_suite/data/k_calibrati
```

```
.json",
      "cosmology assumptions: tfpt_suite/data/k_calibration.json (H0, \u03a9_m, \u03a9_r, z_*)",
      "explicit scale-factor mapping model: tfpt_suite/cosmo_scale_map.py"
    ],
    "maturity": null,
    "module_id": "ux_cosmo_history_sampler",
    "name": "Unconventional: cosmology history sampler (k\u2192\u2113 feasibility + robustness)",
    "objective": [],
    "outputs": [
      "distribution of \u2113_bounce under explicit priors over (N_inflation, N_reheat, T_reheat)",
      "fraction of samples that land in CMB-like \u2113 windows (diagnostic)",
      "best candidates (closest to target \u2113 in log-space)"
    ],
    "question": null,
    "references": [],
    "validation": [
      "report whether plausible priors allow \u2113_bounce to sit in the CMB window without hidden tuning"
    ],
    "what_was_done": []
  },
  "warnings": []
}
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ux_flavor_holdout_search


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{
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      "detail": "candidates=16, rows=16",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "best_candidate_has_finite_chi2",
      "detail": "best chi2_fit=2.475, chi2_holdout=185.887, total=188.362",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "pmns_holdout_evaluated",
      "detail": "pmns_candidates=6 (from 6 permutation scan; best chi2_fit=3.159 chi2_holdout=13.257)",
      "passed": true,
      "severity": null
    }
  ],
  "module_id": "ux_flavor_holdout_search",
  "plot": {
    "flavor_holdout_png": "tfpt-suite/out/unconventional/ux_flavor_holdout_search/flavor_holdout.png"
  },
  "results": {
    "deltas": {
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      "delta_star": 0.608861992029
    },
    "plot": {
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    },
    "pmns_holdout": {
      "reference": {
        "file": "tfpt-suite/tfpt_suite/data/pmns_reference.json",
        "fit_keys": [
          "sin2_theta12",
          "sin2_theta13",
          "sin2_theta23"
        ],
        "holdout_keys": [
          "delta_cp_deg"
        ]
      },
      "rows": [
        {
          "angles_deg": {
            "delta_cp_deg": 90.00000000000031,
            "theta12_deg": 34.3225259039,
            "theta13_deg": 8.74369300841,
            "theta23_deg": 42.46122629316272
          },
          "chi2_fit": 3.15900082137935,
          "chi2_holdout": 13.2570677186,
          "chi2_total": 16.41606853998547,
          "complexity": 0,
          "contrib_fit": [
            {
```

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      "chi2": 0.82926974673,
      "key": "sin2_theta12",
      "mean": 0.307,
      "pred": 0.317927709894,
      "sigma": 0.012
    },
    {
      "chi2": 2.32126692884,
      "key": "sin2_theta13",
      "mean": 0.02224,
      "pred": 0.0231084351589,
      "sigma": 0.00057
    },
    {
      "chi2": 0.00846414580671,
      "key": "sin2_theta23",
      "mean": 0.454,
      "pred": 0.455748015056,
      "sigma": 0.019
    }
  ],
  "contrib_holdout": [
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      "key": "delta_cp_deg",
      "mean": 232.0,
      "pred": 90.00000000000031,
      "sigma": 39.0
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  ],
  "ordering": "normal",
  "perm": [
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    1,
    2
  ]
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{
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    "theta13_deg": 8.74369300841,
    "theta23_deg": 42.46122629316272
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  "chi2_fit": 979.2687783336771,
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      "pred": 0.682072290106,
      "sigma": 0.012
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      "key": "sin2_theta13",
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      "pred": 0.0231084351589,
      "sigma": 0.00057
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      "mean": 0.454,
      "pred": 0.455748015056,
      "sigma": 0.019
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    0,
    2
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    ]
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      "theta13_deg": 33.86913155494883,
      "theta23_deg": 47.48452713251159
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    "chi2_total": 175173.17683285443,
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        "sigma": 0.012
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      {
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        "key": "sin2_theta13",
        "mean": 0.02222,
        "pred": 0.310580898025,
        "sigma": 0.00069
      },
      {
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        "key": "sin2_theta23",
        "mean": 0.568,
        "pred": 0.54330884018,
        "sigma": 0.021
      }
    ],
    "contrib_holdout": [
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        "chi2": 0.00565193663406,
        "key": "delta_cp_deg",
        "mean": 273.0,
        "pred": 271.04533655975695,
        "sigma": 26.0
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    ],
    "ordering": "inverted",
    "perm": [
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  {
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    "complexity": 2,
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        "sigma": 0.012
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        "pred": 0.310580898025,
        "sigma": 0.00069
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        "mean": 0.568,
        "pred": 0.54330884018,
        "sigma": 0.021
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        "pred": 91.04533655975732,
        "sigma": 26.0
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    ],
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    "perm": [
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      0,
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  },
  {
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      "theta12_deg": 15.2574406365,
      "theta13_deg": 54.71397861065461,
      "theta23_deg": 47.29839564078061
    },
    "chi2_fit": 871750.710004112,
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    "chi2_total": 871801.4257311446,
    "complexity": 2,
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        "pred": 0.0692513450712,
        "sigma": 0.012
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        "mean": 0.02222,
        "pred": 0.666310666816,
        "sigma": 0.00069
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        "key": "sin2_theta23",
        "mean": 0.568,
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        "pred": 87.84106428792757,
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    "perm": [
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      2,
      0
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  },
  {
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      },
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        "pred": 0.540071550947,
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      1,
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      "theta13_deg": 8.74369300841,
      "theta23_deg": 42.46122629316272
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    "chi2_fit": 3.15900082137935,
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        "key": "sin2_theta12",
        "mean": 0.307,
        "pred": 0.317927709894,
        "sigma": 0.012
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      {
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        "Vts": 0.0417129383655,
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        "sigma": 9e-05
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    },
    "ckm_ref_abs": {
      "Vcb": 0.0417351623675,
      "Vcd": 0.224386163203,
      "Vcs": 0.973606196563,
      "Vtb": 0.999123828954,
      "Vtd": 0.00647916691196,
      "Vts": 0.0413472467448,
      "Vub": 0.00312260138412,
      "Vud": 0.97447876845,
      "Vus": 0.22445796756
    },
    "contrib_fit_top": [
      {
        "chi2": 0.659039390777,
        "key": "Vus",
        "mean": 0.22501,
        "pred": 0.22445796756,
        "sigma": 0.00068
      },
      {
        "chi2": 0.647707563864,
        "key": "Vud",
        "mean": 0.97435,
        "pred": 0.97447876845,
        "sigma": 0.00016
      },
      {
        "chi2": 0.527407858544,
        "key": "Vcs",
        "mean": 0.97349,
        "pred": 0.973606196563,
        "sigma": 0.00016
      },
      {
        "chi2": 0.506267401064,
        "key": "Vcd",
        "mean": 0.22487,
        "pred": 0.224386163203,
        "sigma": 0.00068
      },
      {
        "chi2": 0.094933408517,
        "key": "Vts",
        "mean": 0.04111,
        "pred": 0.0413472467448,
        "sigma": 0.00077
      }
    ],
    "contrib_holdout": [
      {
        "chi2": 122.25760841601507,
        "key": "Vtd",
        "mean": 0.00858,
        "pred": 0.00647916691196,
        "sigma": 0.00019
      },
      {
        "chi2": 45.84773741234822,
        "key": "Vub",
        "mean": 0.003732,
        "pred": 0.00312260138412,
        "sigma": 9e-05
      }
    ],
    "delta_M": 0.607909036634,
    "delta_star": 0.608861992029,
    "delta_used": 0.607909036634,
    "unitarity_dev_ref": 1.99840144433e-15
  },
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{
  "J_mt": 3.1862274907e-05,
  "J_ref": 3.14843571005e-05,
  "candidate": {
    "complexity": 4,
    "delta_mode": "pi_times_1_minus_delta",
    "delta_source": "delta_star",
    "s13_mode": "A_lam3_times_1_minus_delta"
  },
  "chi2_fit": 2.72733324839,
  "chi2_holdout": 2.37820415529,
  "chi2_total": 5.10553740368344,
  "ckm_mt_abs": {
    "Vcb": 0.0419849467387,
    "Vcd": 0.224312671938,
    "Vcs": 0.973612391794,
    "Vtb": 0.999111443742,
    "Vtd": 0.00888854591775,
    "Vts": 0.0411985040388,
    "Vub": 0.00368608612447,
    "Vud": 0.974476689798,
    "Vus": 0.224458445619
  },
  "ckm_ref_abs": {
    "Vcb": 0.0417350907209,
    "Vcd": 0.224312690318,
    "Vcs": 0.973623129945,
    "Vtb": 0.999121992654,
    "Vtd": 0.00883560890963,
    "Vts": 0.0409533369752,
    "Vub": 0.00366415020497,
    "Vud": 0.974477166986,
    "Vus": 0.224456733082
  },
  "contrib_fit_top": [
    {
      "chi2": 0.692327436225,
      "key": "Vcs",
      "mean": 0.97349,
      "pred": 0.973623129945,
      "sigma": 0.00016
    },
    {
      "chi2": 0.671700003036,
      "key": "Vcd",
      "mean": 0.22487,
      "pred": 0.224312690318,
      "sigma": 0.00068
    },
    {
      "chi2": 0.661990230257,
      "key": "Vus",
      "mean": 0.22501,
      "pred": 0.224456733082,
      "sigma": 0.00068
    },
    {
      "chi2": 0.631696967668,
      "key": "Vud",
      "mean": 0.97435,
      "pred": 0.974477166986,
      "sigma": 0.00016
    },
    {
      "chi2": 0.0413953505326,
      "key": "Vts",
      "mean": 0.04111,
      "pred": 0.0409533369752,
      "sigma": 0.00077
    }
  ],
  "contrib_holdout": [
    {
      "chi2": 1.80985913244,
      "key": "Vtd",
      "mean": 0.00858,
      "pred": 0.00883560890963,
      "sigma": 0.00019
    },
    {
      "chi2": 0.568345022852,
      "key": "Vub",
      "mean": 0.003732,
      "pred": 0.00366415020497,
      "sigma": 9e-05
```

```
      }
    ],
    "delta_M": 0.607909036634,
    "delta_star": 0.608861992029,
    "delta_used": 0.608861992029,
    "unitarity_dev_ref": 8.88178419703e-16
  },
  {
    "J_mt": 3.1973797987e-05,
    "J_ref": 3.15945547206e-05,
    "candidate": {
      "complexity": 5,
      "delta_mode": "pi_times_1_minus_delta",
      "delta_source": "tau_mu",
      "s13_mode": "A_lam3_times_1_minus_delta"
    },
    "chi2_fit": 2.72918490764,
    "chi2_holdout": 2.3993206571,
    "chi2_total": 5.12850556474,
    "ckm_mt_abs": {
      "Vcb": 0.0419849453471,
      "Vcd": 0.224312368865,
      "Vcs": 0.97361246168,
      "Vtb": 0.999111410627,
      "Vtd": 0.00889972823271,
      "Vts": 0.0411968929859,
      "Vub": 0.00369506677986,
      "Vud": 0.9744766575,
      "Vus": 0.224458438179
    },
    "ckm_ref_abs": {
      "Vcb": 0.0417350867553,
      "Vcd": 0.224312382351,
      "Vcs": 0.973623201068,
      "Vtb": 0.999121960041,
      "Vtd": 0.00884672463813,
      "Vts": 0.0409517328907,
      "Vub": 0.00367307733379,
      "Vud": 0.974477137026,
      "Vus": 0.224456717244
    },
    "contrib_fit_top": [
      {
        "chi2": 0.693067361392,
        "key": "Vcs",
        "mean": 0.97349,
        "pred": 0.973623201068,
        "sigma": 0.00016
      },
      {
        "chi2": 0.672442565285,
        "key": "Vcd",
        "mean": 0.22487,
        "pred": 0.224312382351,
        "sigma": 0.00068
      },
      {
        "chi2": 0.662028132385,
        "key": "Vus",
        "mean": 0.22501,
        "pred": 0.224456717244,
        "sigma": 0.00068
      },
      {
        "chi2": 0.631399354306,
        "key": "Vud",
        "mean": 0.97435,
        "pred": 0.974477137026,
        "sigma": 0.00016
      },
      {
        "chi2": 0.0422473905869,
        "key": "Vts",
        "mean": 0.04111,
        "pred": 0.0409517328907,
        "sigma": 0.00077
      }
    ],
    "contrib_holdout": [
      {
        "chi2": 1.97069342338,
        "key": "Vtd",
        "mean": 0.00858,
        "pred": 0.00884672463813,
        "sigma": 0.00019
```

```
      },
      {
        "chi2": 0.428627233718,
        "key": "Vub",
        "mean": 0.003732,
        "pred": 0.00367307733379,
        "sigma": 9e-05
      }
    ],
    "delta_M": 0.607909036634,
    "delta_star": 0.608861992029,
    "delta_used": 0.607909036634,
    "unitarity_dev_ref": 7.43360581994e-16
  },
  {
    "J_mt": 2.71535815689e-05,
    "J_ref": 2.68315122439e-05,
    "candidate": {
      "complexity": 3,
      "delta_mode": "pi_times_1_minus_delta",
      "delta_source": "delta_star",
      "s13_mode": "A_lam3_over_3"
    },
    "chi2_fit": 2.82210898489,
    "chi2_holdout": 47.51763659810416,
    "chi2_total": 50.3397455829968,
    "ckm_mt_abs": {
      "Vcb": 0.0419850248159,
      "Vcd": 0.224305184882,
      "Vcs": 0.973614113356,
      "Vtb": 0.999113301737,
      "Vtd": 0.00887880692043,
      "Vts": 0.0411555230777,
      "Vub": 0.00314133464349,
      "Vud": 0.974478501981,
      "Vus": 0.224458863033
    },
    "ckm_ref_abs": {
      "Vcb": 0.041735167657,
      "Vcd": 0.224305202746,
      "Vcs": 0.973624851676,
      "Vtb": 0.999123828619,
      "Vtd": 0.00882592790591,
      "Vts": 0.0409106108738,
      "Vub": 0.00312263768437,
      "Vud": 0.974478978233,
      "Vus": 0.224457056285
    },
    "contrib_fit_top": [
      {
        "chi2": 0.710350571572,
        "key": "Vcs",
        "mean": 0.97349,
        "pred": 0.973624851676,
        "sigma": 0.00016
      },
      {
        "chi2": 0.689870109537,
        "key": "Vcd",
        "mean": 0.22487,
        "pred": 0.224305202746,
        "sigma": 0.00068
      },
      {
        "chi2": 0.661217024766,
        "key": "Vus",
        "mean": 0.22501,
        "pred": 0.224457056285,
        "sigma": 0.00068
      },
      {
        "chi2": 0.6498197097,
        "key": "Vud",
        "mean": 0.97435,
        "pred": 0.974478978233,
        "sigma": 0.00016
      },
      {
        "chi2": 0.0670535058911,
        "key": "Vts",
        "mean": 0.04111,
        "pred": 0.0409106108738,
        "sigma": 0.00077
      }
    ],
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  "contrib_holdout": [
    {
      "chi2": 45.8422755204,
      "key": "Vub",
      "mean": 0.003732,
      "pred": 0.00312263768437,
      "sigma": 9e-05
    },
    {
      "chi2": 1.67536107766,
      "key": "Vtd",
      "mean": 0.00858,
      "pred": 0.00882592790591,
      "sigma": 0.00019
    }
  ],
  "delta_M": 0.607909036634,
  "delta_star": 0.608861992029,
  "delta_used": 0.608861992029,
  "unitarity_dev_ref": 8.881784197e-16
},
{
  "J_mt": 2.71823989958e-05,
  "J_ref": 2.68599855497e-05,
  "candidate": {
    "complexity": 4,
    "delta_mode": "pi_times_1_minus_delta",
    "delta_source": "tau_mu",
    "s13_mode": "A_lam3_over_3"
  },
  "chi2_fit": 2.82527590794,
  "chi2_holdout": 47.64395650647081,
  "chi2_total": 50.46923241440659,
  "ckm_mt_abs": {
    "Vcb": 0.0419850248159,
    "Vcd": 0.224304822267,
    "Vcs": 0.973614196897,
    "Vtb": 0.999113301737,
    "Vtd": 0.00888796292684,
    "Vts": 0.041153546714,
    "Vub": 0.00314133464349,
    "Vud": 0.974478501981,
    "Vus": 0.224458863033
  },
  "ckm_ref_abs": {
    "Vcb": 0.0417351650638,
    "Vcd": 0.224304835182,
    "Vcs": 0.973624936467,
    "Vtb": 0.999123828728,
    "Vtd": 0.00883502939188,
    "Vts": 0.0409086436326,
    "Vub": 0.0031226375568,
    "Vud": 0.97447898036308,
    "Vus": 0.224457047038
  },
  "contrib_fit_top": [
    {
      "chi2": 0.711244148542,
      "key": "Vcs",
      "mean": 0.97349,
      "pred": 0.973624936467,
      "sigma": 0.00016
    },
    {
      "chi2": 0.690768319895,
      "key": "Vcd",
      "mean": 0.22487,
      "pred": 0.224304835182,
      "sigma": 0.00068
    },
    {
      "chi2": 0.661239138594,
      "key": "Vus",
      "mean": 0.22501,
      "pred": 0.224457047038,
      "sigma": 0.00068
    },
    {
      "chi2": 0.649841174228,
      "key": "Vud",
      "mean": 0.97435,
      "pred": 0.97447898036308,
      "sigma": 0.00016
    },
    {
```

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            "chi2": 0.0683831787699,
            "key": "Vts",
            "mean": 0.04111,
            "pred": 0.0409086436326,
            "sigma": 0.00077
          }
        ],
        "contrib_holdout": [
          {
            "chi2": 45.8422947136,
            "key": "Vub",
            "mean": 0.003732,
            "pred": 0.0031226375568,
            "sigma": 9e-05
          },
          {
            "chi2": 1.80166179284,
            "key": "Vtd",
            "mean": 0.00858,
            "pred": 0.00883502939188,
            "sigma": 0.00019
          }
        ],
        "delta_M": 0.607909036634,
        "delta_star": 0.608861992029,
        "delta_used": 0.607909036634,
        "unitarity_dev_ref": 8.881784197e-16
      }
    ]
  }
},
"schema_version": 1,
"spec": {
  "assumptions": [],
  "determinism": "Deterministic (finite discrete scan; no randomness).",
  "formulas": [
    "holdout split: fit on 7 CKM entries; hold out the small elements Vub and Vtd",
    "no continuous tuning; only discrete convention choices"
  ],
  "gaps": [],
  "inputs": [
    "CKM reference snapshot: tfpt_suite/data/ckm_reference.json (diagnostic, scale-labeled)",
    "SM mt boundary conditions: tfpt_suite/rge_sm.py (from sm_inputs_mz.json)",
    "PyR@TE 2-loop runner: tfpt_suite/rge_pyrate_2loop.py (mt\u2192\u03bc_ref short run)",
    "discrete convention space: {delta_source}\u00d7{s13_mode}\u00d7{delta_mode}"
  ],
  "maturity": null,
  "module_id": "ux_flavor_holdout_search",
  "name": "Unconventional: flavor holdout search (discrete CKM phase-map conventions)",
  "objective": [],
  "outputs": [
    "ranked candidates by \u03c7\u00b2_fit (with \u03c7\u00b2_holdout reported separately)",
    "top-k candidates with full per-entry contributions"
  ],
  "question": null,
  "references": [],
  "validation": [
    "all candidates are evaluated deterministically and yield finite \u03c7\u00b2 values",
    "report the best candidate under the holdout protocol"
  ],
  "what_was_done": []
},
"warnings": []
}
```


ux_gravity_gaugefix_ga


```
{
  "checks": [
    {
      "check_id": "ga_found_laplace_type_candidate",
      "detail": "best |c_nonmin|=0.000e+00 with genome=GaugeFixingGenome(family='lorenz', gamma=1.0, xi=1.0)",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "ga_best_close_to_analytic_optimum",
      "detail": "analytic optimum in chosen family: xi*=gamma=1.0 gives c_nonmin=0.000e+00",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "discrete_closed_form_optimum_is_laplace_type",
      "detail": "best discrete candidate=GaugeFixingGenome(family='lorenz', gamma=1.0, xi=1.0) with c_nonmin=0.0",
```

```
      "passed": true,
      "severity": null
    },
    {
      "check_id": "effective_action_r2_operator_spec_present",
      "detail": "path=tfpt-suite/tfpt_suite/data/effective_action_r2_operator_spec.json",
      "passed": true,
      "severity": null
    }
  ],
  "module_id": "ux_gravity_gaugefix_ga",
  "plot": {
    "gravity_gaugefix_ga_png": "tfpt-suite/out/unconventional/ux_gravity_gaugefix_ga/gravity_gaugefix_ga.png"
  },
  "results": {
    "analytic": {
      "c_nonmin_star": 0.0,
      "family": "lorenz",
      "gamma_eff": 1.0,
      "xi_star": 1.0
    },
    "discrete_optimum": {
      "best": {
        "c_nonmin": 0.0,
        "family": "lorenz",
        "gamma": 1.0,
        "xi": 1.0
      }
    },
    "docking_context": {
      "blocks_count": 4,
      "effective_action_r2_operator_spec": "tfpt-suite/tfpt_suite/data/effective_action_r2_operator_spec.json",
      "spec_note": "OperatorSpec for effective_action_r2 on a 4D constant-curvature background. This file is generated determini
ically from the canonical microscopic action spec (tfpt_suite/data/microscopic_action_tfpt_v25.json) using the K4 closure equati
 for the minimal Laplace-type torsion+ghost block operator."
    },
    "ga": {
      "best": {
        "c_nonmin": 0.0,
        "family": "lorenz",
        "gamma": 1.0,
        "score": 0.0,
        "xi": 1.0
      },
      "elite": 12,
      "generations": 40,
      "population": 64,
      "top10": [
        {
          "c_nonmin": 0.0,
          "family": "lorenz",
          "gamma": 1.0,
          "score": 0.0,
          "xi": 1.0
        },
        {
          "c_nonmin": 0.0,
          "family": "weighted",
          "gamma": 0.5,
          "score": 0.0,
          "xi": 0.5
        },
        {
          "c_nonmin": 0.0,
          "family": "weighted",
          "gamma": 1.0,
          "score": 0.0,
          "xi": 1.0
        },
        {
          "c_nonmin": 0.0,
          "family": "weighted",
          "gamma": 2.0,
          "score": 0.0,
          "xi": 2.0
        },
        {
          "c_nonmin": 0.0,
          "family": "weighted",
          "gamma": 3.0,
          "score": 0.0,
          "xi": 3.0
        },
        {
          "c_nonmin": 0.0,
```

```
          "family": "weighted",
          "gamma": 0.5,
          "score": 0.0,
          "xi": 0.5
        },
        {
          "c_nonmin": 0.0,
          "family": "weighted",
          "gamma": 3.0,
          "score": 0.0,
          "xi": 3.0
        },
        {
          "c_nonmin": 0.0,
          "family": "lorenz",
          "gamma": 1.0,
          "score": 0.0,
          "xi": 1.0
        },
        {
          "c_nonmin": 0.0,
          "family": "weighted",
          "gamma": 1.0,
          "score": 0.0,
          "xi": 1.0
        },
        {
          "c_nonmin": 0.0,
          "family": "lorenz",
          "gamma": 1.0,
          "score": 0.0,
          "xi": 1.0
        }
      ]
    },
    "plot": {
      "gravity_gaugefix_ga_png": "tfpt-suite/out/unconventional/ux_gravity_gaugefix_ga/gravity_gaugefix_ga.png"
    },
    "toy_model": {
      "c_nonmin_definition": "1 - gamma/xi",
      "laplace_type_condition": "c_nonmin=0 \u21d4 xi=gamma"
    }
  },
  "schema_version": 1,
  "spec": {
    "assumptions": [],
    "determinism": "Deterministic given config seed (GA uses Python's random).",
    "formulas": [
      "toy nonminimal coefficient: c_nonmin = 1 - \u03b3/\u03be",
      "Laplace-type achieved when c_nonmin = 0 (\u21d2 \u03be=\u03b3)"
    ],
    "gaps": [],
    "inputs": [
      "toy operator family for a vector torsion mode with gauge parameter \u03be",
      "SuiteConfig.seed (deterministic GA search)",
      "optional context: effective_action_r2 OperatorSpec (for docking narrative)"
    ],
    "maturity": null,
    "module_id": "ux_gravity_gaugefix_ga",
    "name": "Unconventional: gravitation gauge-fixing GA (toy nonminimal \u2192 Laplace-type)",
    "objective": [],
    "outputs": [
      "best genome (family, \u03b3, \u03be) minimizing nonminimal coefficient",
      "population summary and analytic optimum comparison"
    ],
    "question": null,
    "references": [],
    "validation": [
      "GA finds a candidate with |c_nonmin| \u226a 1",
      "best \u03be is close to the analytic minimum \u03be=\u03b3 in the chosen family"
    ],
    "what_was_done": []
  },
  "warnings": []
}
```


ux_matching_metamorphic_audit


```
{
  "checks": [
    {
      "check_id": "alpha3_threshold_up_down_near_identity",
      "detail": "max_rel_err=2.211e-16 (tol=1.0e-05); max_abs_err=5.551e-17; samples=500",
      "passed": true,
```

```
      "severity": null
    },
    {
      "check_id": "match_gauge_finite_delta_up_down_identity",
      "detail": "max_rel_err=3.075e-16 (tol=1.0e-12); max_abs_err=4.441e-16; samples=400",
      "passed": true,
      "severity": null
    }
  ],
  "module_id": "ux_matching_metamorphic_audit",
  "plot": {
    "matching_metamorphic_errors_png": "tfpt-suite/out/unconventional/ux_matching_metamorphic_audit/matching_metamorphic_errors.p
g"
  },
  "results": {
    "alpha3_threshold": {
      "max_abs_error": 5.55111512313e-17,
      "max_rel_error": 2.21086020391e-16,
      "tolerance_rel": 1e-05,
      "worst_case": {
        "abs_error": 5.55111512313e-17,
        "inputs": {
          "alpha3": 0.271628125627
        },
        "label": "alpha3_threshold_up_then_down",
        "outputs": {
          "alpha3_back": 0.271628125627,
          "alpha3_up": 0.271318953139
        },
        "rel_error": 2.04364518965e-16
      }
    },
    "gauge_finite_matching": {
      "max_abs_error": 4.4408920985e-16,
      "max_rel_error": 3.07543437718e-16,
      "tolerance_rel": 1e-12,
      "worst_case": {
        "abs_error": 4.4408920985e-16,
        "inputs": {
          "dalpha2": 6.41402901711e-06,
          "dalpha3": 8.68898652304e-06,
          "dalphaY": -7.68382382367e-06,
          "g2": 0.439191452894,
          "g3": 1.44398857327,
          "gY": 0.230732794729
        },
        "label": "match_gauge_finite_delta_up_then_down",
        "outputs": {
          "g2_back": 0.439191452894,
          "g2_up": 0.439283204051,
          "g3_back": 1.44398857327,
          "g3_up": 1.44402638091,
          "gY_back": 0.230732794729,
          "gY_up": 0.230523458211
        },
        "rel_error": 3.07543437718e-16
      }
    },
    "plot": {
      "matching_metamorphic_errors_png": "tfpt-suite/out/unconventional/ux_matching_metamorphic_audit/matching_metamorphic_error
png"
    },
    "samples": {
      "alpha3": 500,
      "gauge": 400
    }
  },
  "schema_version": 1,
  "spec": {
    "assumptions": [],
    "determinism": "Deterministic given config seed + precision.",
    "formulas": [
      "Metamorphic property examples:",
      "- \u03b13 threshold: down(up(\u03b13)) \u2248 \u03b13 (within truncation order)",
      "- finite gauge matching: down(up(g_i, \u03b4\u03b1)) = g_i (should be exact up to float rounding)"
    ],
    "gaps": [],
    "inputs": [
      "`tfpt_suite/matching.py` primitives",
      "deterministic RNG seed (SuiteConfig.seed)"
    ],
    "maturity": null,
    "module_id": "ux_matching_metamorphic_audit",
    "name": "Unconventional: matching metamorphic audit (invertibility + stability)",
    "objective": [],
```

```
    "outputs": [
      "max abs/rel errors for metamorphic properties",
      "worst-case counterexamples (if any)"
    ],
    "question": null,
    "references": [],
    "validation": [
      "report max observed errors and fail explicitly if they exceed conservative tolerances"
    ],
    "what_was_done": []
  },
  "warnings": []
}
```


ux_omega_b_aps_bridge


```
{
  "checks": [
    {
      "check_id": "aps_spectral_flow_m1",
      "detail": "m=1 periodic: numeric_sf=1, winding=1",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "delta_gamma_equals_2pi",
      "detail": "\u0394\u0393=2\u03c0\u00b7SF with SF=1 \u21d2 \u0394\u0393=6.28318530718",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "K_candidate_equals_4pi_minus_1",
      "detail": "K_candidate=2\u0394\u0393\u22121=11.5663706144 (vs 4\u03c0\u22121)",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "omega_b_pred_positive",
      "detail": "\u03a9_b_pred=0.0489406626655",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "omega_b_pred_close_to_planck_ref_diagnostic",
      "detail": "\u03a9_b_ref=0.0493016923285 \u00b1 8.568114e-04; z=0.421364201619",
      "passed": true,
      "severity": null
    }
  ],
  "module_id": "ux_omega_b_aps_bridge",
  "plot": {
    "omega_b_aps_bridge_png": "tfpt-suite/out/unconventional/ux_omega_b_aps_bridge/omega_b_aps_bridge.png"
  },
  "results": {
    "aps_seam": {
      "delta_gamma": "6.28318530718",
      "epsilon": 0.001,
      "m": 1,
      "spectral_flow": 1,
      "spin": "periodic",
      "winding": 1
    },
    "bridge": {
      "K_candidate": "11.5663706144",
      "assumptions": [
        {
          "id": "aps_seam_term_toy_model",
          "statement": "Use the 1D Dirac-family toy model of the seam operator (Appendix seam) where \u0394\u0393 := 2\u03c0\u00b
SF(U_\u0393) for U_\u0393(\u03b8)=exp(i m \u03b8).",
          "status": "implemented (see aps_eta_gluing)"
        },
        {
          "id": "minimal_nontrivial_class_m_eq_1",
          "statement": "Use the minimal nontrivial winding class m=1 (so SF=1 in the toy model).",
          "status": "checked in aps_eta_gluing (minimal m with SF>0 is 1)"
        },
        {
          "id": "omega_b_coeff_equals_2_delta_gamma_minus_1",
          "statement": "Bridge postulate: the baryon coefficient K := \u03a9_b/\u03b2_rad equals (2\u00b7\u0394\u0393 \u2212 1)
 the same normalization.",
          "status": "conditional / to be replaced by an operator/anomaly-level derivation"
        }
      ],
      "conditional": true,
```

```
      "omega_b_pred": "0.0489406626655"
    },
    "plot": {
      "omega_b_aps_bridge_png": "tfpt-suite/out/unconventional/ux_omega_b_aps_bridge/omega_b_aps_bridge.png"
    },
    "reference": {
      "file": "tfpt-suite/tfpt_suite/data/global_reference_minimal.json",
      "implied_K": "11.6516944056",
      "omega_b_ref": "0.0493016923285",
      "sigma_implied_K": "0.20249416287",
      "sigma_omega_b_ref": "8.568114e-04",
      "z_score": "0.421364201619"
    },
    "tfpt": {
      "beta_rad": "0.0042312895114"
    }
  },
  "schema_version": 1,
  "spec": {
    "assumptions": [],
    "determinism": "Deterministic; no randomness.",
    "formulas": [
      "APS seam term (toy-model): \u0394\u0393 = 2\u03c0 \u00b7 SF(U_\u0393), with minimal nontrivial class m=1 \u21d2 SF=1 \u21
 \u0394\u0393=2\u03c0",
      "bridge (conditional): K_candidate = 2\u00b7\u0394\u0393 \u2212 1  (\u21d2 4\u03c0 \u2212 1)",
      "\u03a9_b_pred = K_candidate \u00b7 beta_rad"
    ],
    "gaps": [],
    "inputs": [
      "TFPT beta_rad = varphi0/(4\u03c0) from constants.py",
      "APS seam toy-model: spectral flow SF(U_\u0393) for U_\u0393(\u03b8)=exp(i m \u03b8) (module `aps_eta_gluing`)",
      "Planck 2018 reference (\u03a9_b h^2 and H0) for a diagnostic implied coefficient K := \u03a9_b/beta_rad"
    ],
    "maturity": null,
    "module_id": "ux_omega_b_aps_bridge",
    "name": "Unconventional: \u03a9_b coefficient bridge via APS seam term (\u0394\u0393)",
    "objective": [],
    "outputs": [
      "\u0394\u0393 from APS spectral flow (m=1)",
      "candidate coefficient K_candidate := 2\u00b7\u0394\u0393 \u2212 1",
      "\u03a9_b prediction using K_candidate (diagnostic vs Planck-derived \u03a9_b)"
    ],
    "question": null,
    "references": [],
    "validation": [
      "show numerically that K_candidate equals (4\u03c0\u22121) once \u0394\u0393=2\u03c0 is fixed by the spectral-flow computa
on",
      "report agreement vs Planck-derived \u03a9_b as diagnostic only"
    ],
    "what_was_done": []
  },
  "warnings": []
}
```


ux_threshold_graph_audit


```
{
  "checks": [
    {
      "check_id": "threshold_table_loaded",
      "detail": "nodes=[('MSigma', 1000.0), ('MG8', 18000000000.0), ('MPhi', 88600000000.0), ('MNR1', 100000000000000.0), ('MNR2
 300000000000000.0), ('MNR3', 800000000000000.0)]",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "segments_ordered_matching_off",
      "detail": "segments=6",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "segments_ordered_matching_on",
      "detail": "segments=6",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "segment_count_matches_expected",
      "detail": "expected=6 from thresholds_in_range=['MSigma', 'MG8', 'MNR1', 'MNR2', 'MNR3']; got=6",
      "passed": true,
      "severity": null
    },
    {
```

```
      "check_id": "matching_off_marks_blocked_thresholds",
      "detail": "publication_grade={'threshold_matching_ok': False, 'blocked_thresholds': ['MSigma', 'MG8', 'MNR1', 'MNR2', 'MNR
], 'note': \"Publication-grade threshold bookkeeping requires matching_active=True at each threshold boundary; if matching is di
bled, segments are labeled 'continuous_by_assumption'.\"}",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "matching_on_is_publication_grade_bookkeeping",
      "detail": "publication_grade={'threshold_matching_ok': True, 'blocked_thresholds': [], 'note': \"Publication-grade thresho
 bookkeeping requires matching_active=True at each threshold boundary; if matching is disabled, segments are labeled 'continuous
y_assumption'.\"}",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "thresholds_marked_publication_grade",
      "detail": "threshold_statuses=[{'threshold_id': 'MSigma', 'status': 'identity_matching', 'component_status': {'gauge': 'ma
hed_1loop_log_only_identity', 'yukawa': 'matched_1loop_log_only_identity', 'quartic': 'matched_1loop_log_only_identity'}}, {'thr
hold_id': 'MG8', 'status': 'identity_matching', 'component_status': {'gauge': 'matched_1loop_log_only_identity', 'yukawa': 'matc
d_1loop_log_only_identity', 'quartic': 'matched_1loop_log_only_identity'}}, {'threshold_id': 'MNR1', 'status': 'identity_matchin
, 'component_status': {'gauge': 'matched_1loop_log_only_identity', 'yukawa': 'matched_1loop_log_only_identity', 'quartic': 'matc
d_1loop_log_only_identity'}}, {'threshold_id': 'MNR2', 'status': 'identity_matching', 'component_status': {'gauge': 'matched_1lo
_log_only_identity', 'yukawa': 'matched_1loop_log_only_identity', 'quartic': 'matched_1loop_log_only_identity'}}, {'threshold_id
 'MNR3', 'status': 'identity_matching', 'component_status': {'gauge': 'matched_1loop_log_only_identity', 'yukawa': 'matched_1loo
log_only_identity', 'quartic': 'matched_1loop_log_only_identity'}}]",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "matching_on_no_blocked_thresholds",
      "detail": "blocked_thresholds=[]",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "threshold_starts_have_explicit_matching_records_when_enabled",
      "detail": "threshold_segments=5, matching_active_true=5",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "below_mz_alpha3_matching_changes_alpha_s",
      "detail": "alpha_s(mc) off=0.346914414, on=0.347983505, delta=+1.069e-03",
      "passed": true,
      "severity": null
    }
  ],
  "module_id": "ux_threshold_graph_audit",
  "plot": {
    "threshold_graph_png": "tfpt-suite/out/unconventional/ux_threshold_graph_audit/threshold_graph.png"
  },
  "results": {
    "below_mz_qcd_matching": {
      "alpha_s_mc_matching_off": 0.346914414088,
      "alpha_s_mc_matching_on": 0.347983505121,
      "delta_alpha_s_mc": 0.00106909103334,
      "mb_GeV": 4.18,
      "mc_GeV": 1.27,
      "mu_ref_mz_GeV": 91.1876
    },
    "boundary": {
      "g_start": [
        0.358711992555,
        0.64833418822,
        1.16763332436
      ],
      "mt_GeV": 172.76,
      "mu_ref_mz_GeV": 91.1876
    },
    "finite_piece_status": {
      "matching_on": [
        {
          "component_status": {
            "gauge": "matched_1loop_log_only_identity",
            "quartic": "matched_1loop_log_only_identity",
            "yukawa": "matched_1loop_log_only_identity"
          },
          "status": "identity_matching",
          "threshold_id": "MSigma"
        },
        {
          "component_status": {
            "gauge": "matched_1loop_log_only_identity",
            "quartic": "matched_1loop_log_only_identity",
```

```
          "yukawa": "matched_1loop_log_only_identity"
        },
        "status": "identity_matching",
        "threshold_id": "MG8"
      },
      {
        "component_status": {
          "gauge": "matched_1loop_log_only_identity",
          "quartic": "matched_1loop_log_only_identity",
          "yukawa": "matched_1loop_log_only_identity"
        },
        "status": "identity_matching",
        "threshold_id": "MNR1"
      },
      {
        "component_status": {
          "gauge": "matched_1loop_log_only_identity",
          "quartic": "matched_1loop_log_only_identity",
          "yukawa": "matched_1loop_log_only_identity"
        },
        "status": "identity_matching",
        "threshold_id": "MNR2"
      },
      {
        "component_status": {
          "gauge": "matched_1loop_log_only_identity",
          "quartic": "matched_1loop_log_only_identity",
          "yukawa": "matched_1loop_log_only_identity"
        },
        "status": "identity_matching",
        "threshold_id": "MNR3"
      }
    ]
  },
  "graph": {
    "edges_matching_off": [
      {
        "matching_active": null,
        "model": "sm_tfpt_2loop_v25",
        "mu_end_GeV": 1000.0,
        "mu_start_GeV": 172.76,
        "patches": [],
        "threshold_at_start": null
      },
      {
        "matching_active": false,
        "model": "e8_sigma_yN_2loop",
        "mu_end_GeV": 18000000000.0,
        "mu_start_GeV": 1000.0,
        "patches": [],
        "threshold_at_start": "MSigma"
      },
      {
        "matching_active": false,
        "model": "e8_sigma_yN_2loop",
        "mu_end_GeV": 100000000000000.0,
        "mu_start_GeV": 18000000000.0,
        "patches": [
          "delta_b3_g8"
        ],
        "threshold_at_start": "MG8"
      },
      {
        "matching_active": false,
        "model": "e8_sigma_yN_2loop",
        "mu_end_GeV": 300000000000000.0,
        "mu_start_GeV": 100000000000000.0,
        "patches": [
          "delta_b3_g8"
        ],
        "threshold_at_start": "MNR1"
      },
      {
        "matching_active": false,
        "model": "e8_sigma_yN_2loop",
        "mu_end_GeV": 800000000000000.0,
        "mu_start_GeV": 300000000000000.0,
        "patches": [
          "delta_b3_g8"
        ],
        "threshold_at_start": "MNR2"
      },
      {
        "matching_active": false,
        "model": "e8_sigma_yN_2loop",
```

```
          "mu_end_GeV": 1e+16,
          "mu_start_GeV": 800000000000000.0,
          "patches": [
            "delta_b3_g8"
          ],
          "threshold_at_start": "MNR3"
        }
      ],
      "edges_matching_on": [
        {
          "matching_active": null,
          "model": "sm_tfpt_2loop_v25",
          "mu_end_GeV": 1000.0,
          "mu_start_GeV": 172.76,
          "patches": [],
          "threshold_at_start": null
        },
        {
          "matching_active": true,
          "model": "e8_sigma_yN_2loop",
          "mu_end_GeV": 180000000000.0,
          "mu_start_GeV": 1000.0,
          "patches": [],
          "threshold_at_start": "MSigma"
        },
        {
          "matching_active": true,
          "model": "e8_sigma_yN_2loop",
          "mu_end_GeV": 1000000000000000.0,
          "mu_start_GeV": 180000000000.0,
          "patches": [
            "delta_b3_g8"
          ],
          "threshold_at_start": "MG8"
        },
        {
          "matching_active": true,
          "model": "e8_sigma_yN_2loop",
          "mu_end_GeV": 3000000000000000.0,
          "mu_start_GeV": 1000000000000000.0,
          "patches": [
            "delta_b3_g8"
          ],
          "threshold_at_start": "MNR1"
        },
        {
          "matching_active": true,
          "model": "e8_sigma_yN_2loop",
          "mu_end_GeV": 8000000000000000.0,
          "mu_start_GeV": 3000000000000000.0,
          "patches": [
            "delta_b3_g8"
          ],
          "threshold_at_start": "MNR2"
        },
        {
          "matching_active": true,
          "model": "e8_sigma_yN_2loop",
          "mu_end_GeV": 1e+16,
          "mu_start_GeV": 8000000000000000.0,
          "patches": [
            "delta_b3_g8"
          ],
          "threshold_at_start": "MNR3"
        }
      ]
    },
    "plot": {
      "threshold_graph_png": "tfpt-suite/out/unconventional/ux_threshold_graph_audit/threshold_graph.png"
    },
    "runs": {
      "matching_off": {
        "publication_grade": {
          "blocked_thresholds": [
            "MSigma",
            "MG8",
            "MNR1",
            "MNR2",
            "MNR3"
          ],
          "note": "Publication-grade threshold bookkeeping requires matching_active=True at each threshold boundary; if matching
s disabled, segments are labeled 'continuous_by_assumption'.",
          "threshold_matching_ok": false
        },
        "segments": [
```

```
        {
          "delta_b3_active": false,
          "model": "sm_tfpt_2loop_v25",
          "mu_end": 1000.0,
          "mu_end_GeV": 1000.0,
          "mu_start": 172.76,
          "mu_start_GeV": 172.76,
          "patches": [],
          "patches_active": [],
          "threshold_actions_at_start": [],
          "threshold_match": null,
          "yN_active_cols": [
            false,
            false,
            false
          ]
        },
        {
          "delta_b3_active": false,
          "model": "e8_sigma_yN_2loop",
          "mu_end": 18000000000.0,
          "mu_end_GeV": 18000000000.0,
          "mu_start": 1000.0,
          "mu_start_GeV": 1000.0,
          "patches": [],
          "patches_active": [],
          "threshold_actions_at_start": [
            {
              "action": "beta_source_switch(sm\u2194e8)",
              "affected_parameters": [
                "g",
                "Yu",
                "Yd",
                "Ye",
                "lambda",
                "yN"
              ],
              "note": "Switch beta source SM\u2192E8 at \u03bc=MSigma (Sigma integrated in). No finite matching implemented ye
",
              "scale_GeV": 1000.0,
              "status": "continuous_by_assumption",
              "threshold_id": "MSigma"
            }
          ],
          "threshold_match": {
            "matching_active": false,
            "note": "Switch beta source SM\u2192E8 at \u03bc=MSigma (Sigma integrated in). No finite matching implemented yet.
            "status": "continuous_by_assumption",
            "threshold_id": "MSigma"
          },
          "threshold_transition_at_start": {
            "action": "beta_source_switch(sm\u2194e8)",
            "affected_parameters": [
              "g",
              "Yu",
              "Yd",
              "Ye",
              "lambda",
              "yN"
            ],
            "note": "Switch beta source SM\u2192E8 at \u03bc=MSigma (Sigma integrated in). No finite matching implemented yet.
            "scale_GeV": 1000.0,
            "status": "continuous_by_assumption",
            "threshold_id": "MSigma"
          },
          "yN_active_cols": [
            false,
            false,
            false
          ]
        },
        {
          "delta_b3_active": true,
          "model": "e8_sigma_yN_2loop",
          "mu_end": 100000000000000.0,
          "mu_end_GeV": 100000000000000.0,
          "mu_start": 18000000000.0,
          "mu_start_GeV": 18000000000.0,
          "patches": [
            "delta_b3_g8"
          ],
          "patches_active": [
            "delta_b3_g8"
          ],
          "threshold_actions_at_start": [
```

```
              {
                "action": "beta_patch(\u0394b3)",
                "affected_parameters": [
                  "g3"
                ],
                "note": "Apply \u0394b3 patch above MG8 (paper v1.06 note). No finite matching implemented yet.",
                "scale_GeV": 18000000000.0,
                "status": "continuous_by_assumption",
                "threshold_id": "MG8"
              }
            ],
            "threshold_match": {
              "matching_active": false,
              "note": "Apply \u0394b3 patch above MG8 (paper v1.06 note). No finite matching implemented yet.",
              "status": "continuous_by_assumption",
              "threshold_id": "MG8"
            },
            "threshold_transition_at_start": {
              "action": "beta_patch(\u0394b3)",
              "affected_parameters": [
                "g3"
              ],
              "note": "Apply \u0394b3 patch above MG8 (paper v1.06 note). No finite matching implemented yet.",
              "scale_GeV": 18000000000.0,
              "status": "continuous_by_assumption",
              "threshold_id": "MG8"
            },
            "yN_active_cols": [
              false,
              false,
              false
            ]
          },
          {
            "delta_b3_active": true,
            "model": "e8_sigma_yN_2loop",
            "mu_end": 300000000000000.0,
            "mu_end_GeV": 300000000000000.0,
            "mu_start": 100000000000000.0,
            "mu_start_GeV": 100000000000000.0,
            "patches": [
              "delta_b3_g8"
            ],
            "patches_active": [
              "delta_b3_g8"
            ],
            "threshold_actions_at_start": [
              {
                "action": "activate_yN_column",
                "affected_parameters": [
                  "yN"
                ],
                "note": "Activate yN column above \u03bc=MNRi via projector. No finite matching implemented in this engine (PMNS
FT does explicit tree-level \u03ba matching).",
                "scale_GeV": 100000000000000.0,
                "status": "continuous_by_assumption",
                "threshold_id": "MNR1"
              }
            ],
            "threshold_match": {
              "matching_active": false,
              "note": "Activate yN column above \u03bc=MNRi via projector. No finite matching implemented in this engine (PMNS E
 does explicit tree-level \u03ba matching).",
              "status": "continuous_by_assumption",
              "threshold_id": "MNR1"
            },
            "threshold_transition_at_start": {
              "action": "activate_yN_column",
              "affected_parameters": [
                "yN"
              ],
              "note": "Activate yN column above \u03bc=MNRi via projector. No finite matching implemented in this engine (PMNS E
 does explicit tree-level \u03ba matching).",
              "scale_GeV": 100000000000000.0,
              "status": "continuous_by_assumption",
              "threshold_id": "MNR1"
            },
            "yN_active_cols": [
              true,
              false,
              false
            ]
          },
          {
            "delta_b3_active": true,
```

```
            "model": "e8_sigma_yN_2loop",
            "mu_end": 800000000000000.0,
            "mu_end_GeV": 800000000000000.0,
            "mu_start": 300000000000000.0,
            "mu_start_GeV": 300000000000000.0,
            "patches": [
              "delta_b3_g8"
            ],
            "patches_active": [
              "delta_b3_g8"
            ],
            "threshold_actions_at_start": [
              {
                "action": "activate_yN_column",
                "affected_parameters": [
                  "yN"
                ],
                "note": "Activate yN column above \u03bc=MNRi via projector. No finite matching implemented in this engine (PMNS
FT does explicit tree-level \u03ba matching).",
                "scale_GeV": 300000000000000.0,
                "status": "continuous_by_assumption",
                "threshold_id": "MNR2"
              }
            ],
            "threshold_match": {
              "matching_active": false,
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 does explicit tree-level \u03ba matching).",
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              false
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            "mu_start_GeV": 800000000000000.0,
            "patches": [
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            ],
            "patches_active": [
              "delta_b3_g8"
            ],
            "threshold_actions_at_start": [
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                "affected_parameters": [
                  "yN"
                ],
                "note": "Activate yN column above \u03bc=MNRi via projector. No finite matching implemented in this engine (PMNS
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                "status": "continuous_by_assumption",
                "threshold_id": "MNR3"
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 does explicit tree-level \u03ba matching).",
              "status": "continuous_by_assumption",
              "threshold_id": "MNR3"
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            "threshold_transition_at_start": {
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              "affected_parameters": [
                "yN"
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            "status": "continuous_by_assumption",
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            true,
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          ]
        }
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          "action": "beta_source_switch(sm\u2194e8)",
          "affected_parameters": [
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            "Yu",
            "Yd",
            "Ye",
            "lambda",
            "yN"
          ],
          "note": "Switch beta source SM\u2192E8 at \u03bc=MSigma (Sigma integrated in). No finite matching implemented yet.",
          "scale_GeV": 1000.0,
          "status": "continuous_by_assumption",
          "threshold_id": "MSigma"
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          "action": "beta_patch(\u0394b3)",
          "affected_parameters": [
            "g3"
          ],
          "note": "Apply \u0394b3 patch above MG8 (paper v1.06 note). No finite matching implemented yet.",
          "scale_GeV": 18000000000.0,
          "status": "continuous_by_assumption",
          "threshold_id": "MG8"
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          "action": "activate_yN_column",
          "affected_parameters": [
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          "note": "Activate yN column above \u03bc=MNRi via projector. No finite matching implemented in this engine (PMNS EFT
oes explicit tree-level \u03ba matching).",
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          "status": "continuous_by_assumption",
          "threshold_id": "MNR1"
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          "affected_parameters": [
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oes explicit tree-level \u03ba matching).",
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          "status": "continuous_by_assumption",
          "threshold_id": "MNR2"
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          "affected_parameters": [
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oes explicit tree-level \u03ba matching).",
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          "status": "continuous_by_assumption",
          "threshold_id": "MNR3"
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        "note": "Publication-grade threshold bookkeeping requires matching_active=True at each threshold boundary; if matching
s disabled, segments are labeled 'continuous_by_assumption'.",
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            "mu_start_GeV": 172.76,
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            "patches_active": [],
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            "threshold_match": null,
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            ]
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            "delta_b3_active": false,
            "model": "e8_sigma_yN_2loop",
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            "mu_end_GeV": 18000000000.0,
            "mu_start": 1000.0,
            "mu_start_GeV": 1000.0,
            "patches": [],
            "patches_active": [],
            "threshold_actions_at_start": [
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                "action": "beta_source_switch(sm\u2194e8)",
                "affected_parameters": [
                  "g",
                  "Yu",
                  "Yd",
                  "Ye",
                  "lambda",
                  "yN"
                ],
                "note": "Switch beta source SM\u2192E8 at \u03bc=MSigma (Sigma integrated in). Matching enabled (loop_order=1; 1
oop is identity at \u03bc=threshold).",
                "scale_GeV": 1000.0,
                "status": "matched_1loop_log_only_identity",
                "threshold_id": "MSigma"
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                "deltas": {},
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                    "Sigma"
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                  "finite_delta_alpha_input": {},
                  "loop_order": 1,
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                  "threshold_id": "MSigma"
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finite pieces require explicit inputs or higher-loop decoupling constants",
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                "deltas": {},
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                    "Sigma"
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                  "loop_order": 1,
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                  "scheme": "MSbar",
                  "threshold_id": "MSigma"
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                "loop_order": 1,
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                "threshold_id": "MSigma",
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                  "Ye": 0.0103418663719,
                  "Yu": 0.859013095294,
                  "yN": 0.0
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              },
              "note": "identity matching at \u03bc=threshold (1-loop decoupling is log-only, so the step vanishes at \u03bc=M)
top pole\u2192MSbar(mt) is handled in rge_sm.sm_boundary_conditions_at_mt",
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            "affected_parameters": [
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              "Yu",
              "Yd",
              "Ye",
              "lambda",
              "yN"
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            "scale_GeV": 1000.0,
            "status": "matched_1loop_log_only_identity",
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          "mu_end_GeV": 1000000000000000.0,
          "mu_start": 18000000000.0,
          "mu_start_GeV": 18000000000.0,
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              "affected_parameters": [
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              "note": "Apply \u0394b3 patch above MG8 (paper v1.06 note). Matching enabled (loop_order=1; 1-loop is identity a
\u03bc=threshold).",
              "scale_GeV": 18000000000.0,
              "status": "matched_1loop_log_only_identity",
              "threshold_id": "MG8"
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                    "Sigma"
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                  "finite_delta_alpha_input": {},
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finite pieces require explicit inputs or higher-loop decoupling constants",
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                    "Sigma",
                    "G8"
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                    "SM",
                    "Sigma"
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                  "finite_delta_quartic_input": {},
                  "loop_order": 1,
                  "mu_thr_GeV": 18000000000.0,
                  "scheme": "MSbar",
                  "threshold_id": "MG8"
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                "status": "matched_1loop_log_only_identity"
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              "scheme": "MSbar",
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                    "Sigma"
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                  "finite_delta_yukawa_input": {},
                  "loop_order": 1,
                  "mu_thr_GeV": 18000000000.0,
                  "scheme": "MSbar",
                  "threshold_id": "MG8",
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                    "Yd": 0.00802333749963,
                    "Ye": 0.0103018898467,
                    "Yu": 0.530916579393,
                    "yN": 0.0
                  }
                },
                "note": "identity matching at \u03bc=threshold (1-loop decoupling is log-only, so the step vanishes at \u03bc=M)
top pole\u2192MSbar(mt) is handled in rge_sm.sm_boundary_conditions_at_mt",
                "status": "matched_1loop_log_only_identity"
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              "action": "beta_patch(\u0394b3)",
              "affected_parameters": [
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              "note": "Apply \u0394b3 patch above MG8 (paper v1.06 note). Matching enabled (loop_order=1; 1-loop is identity at 
03bc=threshold).",
              "scale_GeV": 18000000000.0,
              "status": "matched_1loop_log_only_identity",
              "threshold_id": "MG8"
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            "delta_b3_active": true,
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            "mu_start_GeV": 100000000000000.0,
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                "affected_parameters": [
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reshold).",
                "scale_GeV": 100000000000000.0,
                "status": "matched_1loop_log_only_identity",
                "threshold_id": "MNR1"
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                "deltas": {},
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                    "Sigma",
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                  "finite_delta_alpha_input": {},
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finite pieces require explicit inputs or higher-loop decoupling constants",
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                    "Sigma",
                    "G8"
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                  "threshold_id": "MNR1"
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                "note": "identity matching at \u03bc=threshold (explicit); finite quartic matching not implemented yet",
                "status": "matched_1loop_log_only_identity"
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              "scheme": "MSbar",
              "threshold_id": "MNR1",
              "yukawa": {
                "deltas": {},
                "details": {
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                    "Sigma",
                    "G8",
                    "NR1"
                  ],
                  "active_fields_before": [
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                  "finite_delta_yukawa_input": {},
                  "loop_order": 1,
                  "mu_thr_GeV": 100000000000000.0,
                  "scheme": "MSbar",
                  "threshold_id": "MNR1",
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                    "Ye": 0.00992023999258,
                    "Yu": 0.45040193527,
                    "yN": 0.0
                  }
                },
                "note": "identity matching at \u03bc=threshold (1-loop decoupling is log-only, so the step vanishes at \u03bc=M)
top pole\u2192MSbar(mt) is handled in rge_sm.sm_boundary_conditions_at_mt",
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shold).",
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              "status": "matched_1loop_log_only_identity",
              "threshold_id": "MNR1"
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            "yN_active_cols": [
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              false,
              false
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          },
          {
            "delta_b3_active": true,
            "model": "e8_sigma_yN_2loop",
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            "mu_end_GeV": 800000000000000.0,
            "mu_start": 300000000000000.0,
            "mu_start_GeV": 300000000000000.0,
            "patches": [
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            ],
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              "delta_b3_g8"
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            "threshold_actions_at_start": [
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reshold).",
                "scale_GeV": 300000000000000.0,
                "status": "matched_1loop_log_only_identity",
                "threshold_id": "MNR2"
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                "deltas": {},
                "details": {
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                    "Sigma",
                    "G8",
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                  "active_fields_before": [
                    "SM",
                    "Sigma",
                    "G8",
                    "NR1"
                  ],
                  "direction": "up",
                  "finite_delta_alpha_applied": {},
                  "finite_delta_alpha_input": {},
                  "loop_order": 1,
                  "mu_thr_GeV": 300000000000000.0,
                  "scheme": "MSbar",
                  "threshold_id": "MNR2"
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                "note": "identity matching at \u03bc=threshold (1-loop decoupling is log-only, so the step vanishes at \u03bc=M)
finite pieces require explicit inputs or higher-loop decoupling constants",
                "status": "matched_1loop_log_only_identity"
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              "matching_active": true,
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                    "Sigma",
                    "G8",
                    "NR1",
                    "NR2"
                  ],
                  "active_fields_before": [
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                    "NR1"
                  ],
                  "direction": "up",
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                  "loop_order": 1,
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                "status": "matched_1loop_log_only_identity"
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                "deltas": {},
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                    "NR1",
                    "NR2"
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                    "G8",
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                  "loop_order": 1,
                  "mu_thr_GeV": 300000000000000.0,
                  "scheme": "MSbar",
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```
                    "Ye": 0.00986257983532,
                    "Yu": 0.441560098763,
                    "yN": 0.0
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top pole\u2192MSbar(mt) is handled in rge_sm.sm_boundary_conditions_at_mt",
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shold).",
              "scale_GeV": 300000000000000.0,
              "status": "matched_1loop_log_only_identity",
              "threshold_id": "MNR2"
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            "yN_active_cols": [
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              true,
              false
            ]
          },
          {
            "delta_b3_active": true,
            "model": "e8_sigma_yN_2loop",
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            "mu_end_GeV": 1e+16,
            "mu_start": 800000000000000.0,
            "mu_start_GeV": 800000000000000.0,
            "patches": [
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            ],
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                "affected_parameters": [
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reshold).",
                "scale_GeV": 800000000000000.0,
                "status": "matched_1loop_log_only_identity",
                "threshold_id": "MNR3"
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                "details": {
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                    "Sigma",
                    "G8",
                    "NR1",
                    "NR2",
                    "NR3"
                  ],
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                    "SM",
                    "Sigma",
                    "G8",
                    "NR1",
                    "NR2"
                  ],
                  "direction": "up",
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                  "finite_delta_alpha_input": {},
                  "loop_order": 1,
                  "mu_thr_GeV": 800000000000000.0,
                  "scheme": "MSbar",
                  "threshold_id": "MNR3"
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                "note": "identity matching at \u03bc=threshold (1-loop decoupling is log-only, so the step vanishes at \u03bc=M)
finite pieces require explicit inputs or higher-loop decoupling constants",
                "status": "matched_1loop_log_only_identity"
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                  "mu_thr_GeV": 800000000000000.0,
                  "scheme": "MSbar",
                  "threshold_id": "MNR3"
                },
                "note": "identity matching at \u03bc=threshold (explicit); finite quartic matching not implemented yet",
                "status": "matched_1loop_log_only_identity"
              },
              "scheme": "MSbar",
              "threshold_id": "MNR3",
              "yukawa": {
                "deltas": {},
                "details": {
                  "active_fields_after": [
                    "SM",
                    "Sigma",
                    "G8",
                    "NR1",
                    "NR2",
                    "NR3"
                  ],
                  "active_fields_before": [
                    "SM",
                    "Sigma",
                    "G8",
                    "NR1",
                    "NR2"
                  ],
                  "direction": "up",
                  "finite_delta_yukawa_applied": {},
                  "finite_delta_yukawa_input": {},
                  "loop_order": 1,
                  "mu_thr_GeV": 800000000000000.0,
                  "scheme": "MSbar",
                  "threshold_id": "MNR3",
                  "yukawa_maxabs_input": {
                    "Yd": 0.00632286091815,
                    "Ye": 0.00980964505462,
                    "Yu": 0.433891162003,
                    "yN": 0.0
                  }
                },
                "note": "identity matching at \u03bc=threshold (1-loop decoupling is log-only, so the step vanishes at \u03bc=M)
top pole\u2192MSbar(mt) is handled in rge_sm.sm_boundary_conditions_at_mt",
                "status": "matched_1loop_log_only_identity"
              }
            },
            "threshold_transition_at_start": {
              "action": "activate_yN_column",
              "affected_parameters": [
                "yN"
              ],
              "note": "Activate yN column above \u03bc=MNRi via projector. Matching enabled (loop_order=1; identity at \u03bc=th
shold).",
              "scale_GeV": 800000000000000.0,
              "status": "matched_1loop_log_only_identity",
              "threshold_id": "MNR3"
            },
            "yN_active_cols": [
              true,
              true,
              true
            ]
```

```
          }
        ],
        "threshold_rules": [
          {
            "action": "beta_source_switch(sm\u2194e8)",
            "affected_parameters": [
              "g",
              "Yu",
              "Yd",
              "Ye",
              "lambda",
              "yN"
            ],
            "note": "Switch beta source SM\u2192E8 at \u03bc=MSigma (Sigma integrated in). Matching enabled (loop_order=1; 1-loo
is identity at \u03bc=threshold).",
            "scale_GeV": 1000.0,
            "status": "matched_1loop_log_only_identity",
            "threshold_id": "MSigma"
          },
          {
            "action": "beta_patch(\u0394b3)",
            "affected_parameters": [
              "g3"
            ],
            "note": "Apply \u0394b3 patch above MG8 (paper v1.06 note). Matching enabled (loop_order=1; 1-loop is identity at \u
bc=threshold).",
            "scale_GeV": 18000000000.0,
            "status": "matched_1loop_log_only_identity",
            "threshold_id": "MG8"
          },
          {
            "action": "activate_yN_column",
            "affected_parameters": [
              "yN"
            ],
            "note": "Activate yN column above \u03bc=MNRi via projector. Matching enabled (loop_order=1; identity at \u03bc=thre
old).",
            "scale_GeV": 100000000000000.0,
            "status": "matched_1loop_log_only_identity",
            "threshold_id": "MNR1"
          },
          {
            "action": "activate_yN_column",
            "affected_parameters": [
              "yN"
            ],
            "note": "Activate yN column above \u03bc=MNRi via projector. Matching enabled (loop_order=1; identity at \u03bc=thre
old).",
            "scale_GeV": 300000000000000.0,
            "status": "matched_1loop_log_only_identity",
            "threshold_id": "MNR2"
          },
          {
            "action": "activate_yN_column",
            "affected_parameters": [
              "yN"
            ],
            "note": "Activate yN column above \u03bc=MNRi via projector. Matching enabled (loop_order=1; identity at \u03bc=thre
old).",
            "scale_GeV": 800000000000000.0,
            "status": "matched_1loop_log_only_identity",
            "threshold_id": "MNR3"
          }
        ]
      }
    },
    "threshold_table": {
      "file": "tfpt-suite/tfpt_suite/data/rge_thresholds_v25.json",
      "mu_uv_GeV": 1e+16,
      "nodes": [
        {
          "note": "from rge_thresholds_v25.json",
          "scale_GeV": 1000.0,
          "threshold_id": "MSigma"
        },
        {
          "note": "from rge_thresholds_v25.json",
          "scale_GeV": 18000000000.0,
          "threshold_id": "MG8"
        },
        {
          "note": "from rge_thresholds_v25.json",
          "scale_GeV": 88600000000.0,
          "threshold_id": "MPhi"
        },
```

```
        {
          "note": "from rge_thresholds_v25.json",
          "scale_GeV": 100000000000000.0,
          "threshold_id": "MNR1"
        },
        {
          "note": "from rge_thresholds_v25.json",
          "scale_GeV": 300000000000000.0,
          "threshold_id": "MNR2"
        },
        {
          "note": "from rge_thresholds_v25.json",
          "scale_GeV": 800000000000000.0,
          "threshold_id": "MNR3"
        }
      ]
    }
  },
  "schema_version": 1,
  "spec": {
    "assumptions": [],
    "determinism": "Deterministic given config seed; no stochastic components.",
    "formulas": [
      "segments are those used by run_flavor_rge_2loop_thresholds (piecewise integration in ln \u03bc)",
      "threshold_rules declare the action at each threshold (beta switch, \u0394b3 patch, yN activation)"
    ],
    "gaps": [],
    "inputs": [
      "threshold table: tfpt_suite/data/rge_thresholds_v25.json",
      "SM MZ inputs: tfpt_suite/data/sm_inputs_mz.json (to build a consistent mt boundary)",
      "PyR@TE PythonOutput registry: tfpt_suite/data/pyrate_pythonoutputs.json"
    ],
    "maturity": null,
    "module_id": "ux_threshold_graph_audit",
    "name": "Unconventional: threshold graph audit (segments + matching bookkeeping)",
    "objective": [],
    "outputs": [
      "threshold nodes (sorted)",
      "segment edges extracted from the 2-loop runner",
      "matching-on vs matching-off comparison (publication-grade bookkeeping flags)"
    ],
    "question": null,
    "references": [],
    "validation": [
      "graph contains expected nodes and ordered segments",
      "matching_off marks thresholds as 'continuous_by_assumption'",
      "matching_on records explicit match_* outcomes at thresholds (even if identity at 1-loop)",
      "thresholds are tagged as finite_pieces_implemented vs identity_matching when matching is enabled",
      "matching_on has no blocked thresholds"
    ],
    "what_was_done": []
  },
  "warnings": []
}
```


ux_torsion_regime_designer


```
{
  "checks": [
    {
      "check_id": "vetted_bounds_loaded",
      "detail": "bounds=4; tightest=A_X:2.100e-31 GeV",
      "passed": true,
      "severity": null
    },
    {
      "check_id": "proposals_generated",
      "detail": "proposals=2 (compatible with torsion_regimes.json schema)",
      "passed": true,
      "severity": null
    }
  ],
  "module_id": "ux_torsion_regime_designer",
  "plot": {
    "torsion_regime_designer_png": "tfpt-suite/out/unconventional/ux_torsion_regime_designer/torsion_regime_designer.png"
  },
  "results": {
    "anchors": [
      {
        "S_mu_pred_cspin_1_GeV": 3.2396753580225e-56,
        "c_spin_max_to_saturate_tightest_bound": 6.48213097896e+24,
        "coupling_kind": "Mpl_reduced",
        "delta_nu_Hz_cspin_1": 1.17502502449e-32,
        "label": "laboratory_electron_gas",
```

```
        "n_unit": "cm^-3",
        "n_value": 1e+23,
        "polarization": 0.5,
        "spin_per_particle": 0.5
      },
      {
        "S_mu_pred_cspin_1_GeV": 3.28322384301e-31,
        "c_spin_max_to_saturate_tightest_bound": 0.639615238075,
        "coupling_kind": "TFPT_M",
        "delta_nu_Hz_cspin_1": 1.19081998972e-07,
        "label": "nuclear_matter_core",
        "n_unit": "fm^-3",
        "n_value": 0.16,
        "polarization": 0.5,
        "spin_per_particle": 0.5
      },
      {
        "S_mu_pred_cspin_1_GeV": 4.10402980376e-30,
        "c_spin_max_to_saturate_tightest_bound": 0.051169219046,
        "coupling_kind": "TFPT_M",
        "delta_nu_Hz_cspin_1": 1.48852498715e-06,
        "label": "extreme_dense_spin_fluid",
        "n_unit": "fm^-3",
        "n_value": 1.0,
        "polarization": 1.0,
        "spin_per_particle": 0.5
      }
    ],
    "bounds": {
      "all": [
        {
          "abs_max_GeV": 2.1e-31,
          "component": "X",
          "label": "A_X",
          "source": "Kosteleck\u00fd\u2013Russell\u2013Tasson 2008 (Phys. Rev. Lett. 100, 111102), arXiv:0712.4393 Eq. (6)"
        },
        {
          "abs_max_GeV": 2.5e-31,
          "component": "Y",
          "label": "A_Y",
          "source": "Kosteleck\u00fd\u2013Russell\u2013Tasson 2008 (Phys. Rev. Lett. 100, 111102), arXiv:0712.4393 Eq. (6)"
        },
        {
          "abs_max_GeV": 1e-29,
          "component": "Z",
          "label": "A_Z",
          "source": "Kosteleck\u00fd\u2013Russell\u2013Tasson 2008 (Phys. Rev. Lett. 100, 111102), arXiv:0712.4393 Eq. (6)"
        },
        {
          "abs_max_GeV": 2.9e-27,
          "component": "T",
          "label": "A_T",
          "source": "Kosteleck\u00fd\u2013Russell\u2013Tasson 2008 (Phys. Rev. Lett. 100, 111102), arXiv:0712.4393 Eq. (6)"
        }
      ],
      "file": "tfpt-suite/tfpt_suite/data/torsion_bounds_vetted.json",
      "tightest": {
        "abs_max_GeV": 2.1e-31,
        "component": "X",
        "label": "A_X",
        "source": "Kosteleck\u00fd\u2013Russell\u2013Tasson 2008 (Phys. Rev. Lett. 100, 111102), arXiv:0712.4393 Eq. (6)"
      }
    },
    "plot": {
      "torsion_regime_designer_png": "tfpt-suite/out/unconventional/ux_torsion_regime_designer/torsion_regime_designer.png"
    },
    "proposals": [
      {
        "c_spin": 1.0,
        "compare_to_bounds": true,
        "coupling_scale": {
          "kind": "Mpl_reduced"
        },
        "id": "spin_medium_candidate_1",
        "label": "Spin-polarized medium candidate 1 (Mpl_reduced)",
        "model": "spin_polarized_medium",
        "note": "Generated by ux_torsion_regime_designer. Toy model: |S_mu| ~ c_spin*(pol*spin*n)/M_eff^2. c_spin is not derived
ere; it is a target for the microscopic operator derivation. Chosen c_spin=1 (\u22480.5*c_spin_max) to stay safely below the tig
est bound.",
        "number_density": {
          "unit": "cm^-3",
          "value": 9.9421658747e+25
        },
        "polarization": 0.874415766701,
        "spin_per_particle": 0.5
```

```
      },
      {
        "c_spin": 0.506949393793,
        "compare_to_bounds": true,
        "coupling_scale": {
          "kind": "TFPT_M"
        },
        "id": "spin_medium_candidate_2",
        "label": "Spin-polarized medium candidate 2 (TFPT_M)",
        "model": "spin_polarized_medium",
        "note": "Generated by ux_torsion_regime_designer. Toy model: |S_mu| ~ c_spin*(pol*spin*n)/M_eff^2. c_spin is not derived
ere; it is a target for the microscopic operator derivation. Chosen c_spin=0.507 (\u22480.5*c_spin_max) to stay safely below the
ightest bound.",
        "number_density": {
          "unit": "fm^-3",
          "value": 0.281239233967
        },
        "polarization": 0.17944785799,
        "spin_per_particle": 0.5
      }
    ],
    "sampling": {
      "best_mpl_reduced": {
        "S_mu_pred_cspin_1_GeV": 5.63287965357476e-53,
        "c_spin_max_to_saturate_tightest_bound": 3.72811089381e+21,
        "coupling_kind": "Mpl_reduced",
        "delta_nu_Hz_cspin_1": 2.04303636057e-29,
        "n_unit": "cm^-3",
        "n_value": 9.9421658747e+25,
        "polarization": 0.874415766701,
        "spin_per_particle": 0.5
      },
      "best_tfpt_M": {
        "S_mu_pred_cspin_1_GeV": 2.07121265526e-31,
        "c_spin_max_to_saturate_tightest_bound": 1.01389878759,
        "coupling_kind": "TFPT_M",
        "delta_nu_Hz_cspin_1": 7.51225487746e-08,
        "n_unit": "fm^-3",
        "n_value": 0.281239233967,
        "polarization": 0.17944785799,
        "spin_per_particle": 0.5
      },
      "candidates_kept": 1200,
      "samples": 1200
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  },
  "schema_version": 1,
  "spec": {
    "assumptions": [],
    "determinism": "Deterministic given config seed (random sampling for scenario exploration).",
    "formulas": [
      "toy spin-medium model: |S_mu| ~ c_spin * (pol * spin_per_particle * n) / M_eff^2",
      "compute c_spin_max := bound / S_pred(c_spin=1) for saturation targets"
    ],
    "gaps": [],
    "inputs": [
      "vetted bounds: tfpt_suite/data/torsion_bounds_vetted.json (A_mu component-wise limits)",
      "TFPT scale M from constants.py (for coupling_kind='TFPT_M')"
    ],
    "maturity": null,
    "module_id": "ux_torsion_regime_designer",
    "name": "Unconventional: torsion regime designer (spin-polarized medium + bound saturation targets)",
    "objective": [],
    "outputs": [
      "tightest bound summary",
      "scenario table (S_pred for c_spin=1, and c_spin needed to saturate bounds)",
      "JSON regime proposals compatible with tfpt_suite/data/torsion_regimes.json"
    ],
    "question": null,
    "references": [],
    "validation": [
      "produce at least one explicit regime proposal (even if conservative)",
      "make all assumptions explicit (toy model; c_spin is a derivation target)"
    ],
    "what_was_done": []
  },
  "warnings": []
}
```