Deterministic Fifth-Force Falsification for a Higgs-Mixed Scalar Portal
Using Eöt–Wash Yukawa Limits

Author Name(s)
Affiliation(s)
email@domain

January 22, 2026

Abstract

This note transcribes a lab-mode analysis into a reviewer-proof, publication-style form. We treat the torsion-balance Yukawa constraint as an *exact falsification check* for a specific portal mapping rather than a generic parameter scan. The key observable is the ratio $r(\lambda) = \alpha_{\text{pred}}/\alpha_{\max}(\lambda)$. In the real-only window considered here, the closest-approach result $r_{\max} \simeq 2.4\times10^{-9}$ implies the mapping would need to be wrong by $\mathcal{O}(10^8)$ (multiplicatively) for this channel to become near-detectable or excluding. We also summarize a robust workflow: fixed-point mapping sweeps, real-domain envelope construction, targeted mixture sampling, and audit-ready outputs.

Contents

1 Context and the core observable

Temporary URLs and link rot are a practical reproducibility hazard, so the pipeline should be built around versioned, permanent artifacts (see Sec. 8). Science-wise, the real-only result $r_{\max} \approx 2.4 \times 10^{-9}$ is an unusually clean outcome: it is dimensionless, operationally meaningful, and difficult to critique as a presentation artifact.

Define

$$r(\lambda) \;=\; \frac{\alpha_{\text{pred}}(\lambda)}{\alpha_{\max}(\lambda)}\,, \tag{1}$$

where $\alpha_{\max}(\lambda)$ is the experimental upper bound on Yukawa strength at range λ, and $\alpha_{\text{pred}}(\lambda)$ is the model prediction under a specified mapping.

2 Crisp scaling numbers from the real-only maximum

Let $r_{\max} = 2.4 \times 10^{-9}$. The multiplicative scale factors required on α_{pred} to reach:

- near-detectable-ish $r = 0.1$:

$$s_{0.1} = \frac{0.1}{2.4 \times 10^{-9}} = \frac{1}{2.4} \times 10^{8} \approx 4.1667 \times 10^{7}\,, \tag{2}$$

- the exclusion boundary $r = 1$:

$$s_{1} = \frac{1}{2.4 \times 10^{-9}} = \frac{1}{2.4} \times 10^{9} \approx 4.1667 \times 10^{8}\,. \tag{3}$$

The corresponding "orders of magnitude below" statement is

$$\log_{10}\!\left(\frac{1}{2.4 \times 10^{-9}}\right) = \log_{10}(4.1667 \times 10^{8}) \approx 8.62\,. \tag{4}$$

This single scaling sentence is useful because it converts a null result into:

> *"The model-to-observable mapping would need to change by $\sim 10^{8}$ to matter in this experimental window."*

3 Exact falsification check for a Higgs-mixed scalar portal

3.1 Experimental template

Eöt–Wash constraints are commonly presented as an upper bound on Yukawa deviations of the form

$$V(r) = -\,\frac{G m_1 m_2}{r}\left(1 + \alpha\, e^{-r/\lambda}\right). \tag{5}$$

To test a scalar mediator, the mapping needs:

- mass $\rightarrow$ range: $\lambda = \hbar/(m_\phi c)$,
- coupling $\rightarrow$ Yukawa strength: $\alpha = \alpha(m_\phi; \text{model parameters})$.

If the pipeline uses a placeholder such as $\alpha_{\text{pred}} = \alpha_{\text{eff}}^2$ without physical normalization, then $r \ll 1$ can mean only "the placeholder is tiny," not "the scalar is safe."

3.2 Higgs mixing bridge and the $K \sin^2\theta$ normalization

For an unscreened scalar coupling through Higgs mixing, the macroscopic Yukawa strength can be written

$$\alpha \approx K\,\sin^2\theta, \qquad K = \frac{f_N^2}{4\pi}\left(\frac{\bar{M}_{\rm Pl}}{v}\right)^2, \tag{6}$$

where f_N is the effective nucleon scalar form factor, $\bar{M}_{\rm Pl}$ is the reduced Planck mass, and $v \simeq 246\,\mathrm{GeV}$ is the Higgs vacuum expectation value.

Given a digitized $\alpha_{\rm max}(\lambda)$ curve, this implies the bound

$$\theta_{\rm max}(\lambda)\ \approx\ \sqrt{\frac{\alpha_{\rm max}(\lambda)}{K}} \qquad \text{(small-angle regime)}. \tag{7}$$

In the window reported in the lab notes, the inferred bounds were:

- $\theta_{\rm max}$ ranging from $\sim 7.9\times10^{-13}$ down to $\sim 6.7\times10^{-17}$ across $\lambda \approx 3.0\times10^{-5}\,\mathrm{m}$ to $9.3\times10^{-4}\,\mathrm{m}$,
- corresponding mediator masses $m_\phi \approx 2.1\times10^{-4}\,\mathrm{eV}$ to $6.6\times10^{-3}\,\mathrm{eV}$ (via $\lambda = \hbar/(m_\phi c)$).

This yields a clean falsifier sentence:

> *If the model predicts $\theta(\lambda) > \theta_{\rm max}(\lambda)$ anywhere in the real-covered window, it is excluded by Eöt–Wash; if $\theta(\lambda) < \theta_{\rm max}(\lambda)$ everywhere, it is allowed (and likely undetectable in that window).*

3.3 Portal coefficient bound

For a typical Higgs-portal term

$$\mathcal{L} \supset \mu\, S\, |H|^2, \tag{8}$$

the small-mixing limit gives

$$\theta \approx \frac{\mu v}{m_h^2 - m_\phi^2} \approx \frac{\mu v}{m_h^2} \qquad (m_\phi \ll m_h). \tag{9}$$

Therefore,

$$\mu_{\rm max}(\lambda) \approx \theta_{\rm max}(\lambda)\,\frac{m_h^2}{v}. \tag{10}$$

Using $m_h \simeq 125\,\mathrm{GeV}$ and $v \simeq 246\,\mathrm{GeV}$,

$$\frac{m_h^2}{v} \approx \frac{125^2}{246}\,\mathrm{GeV} \approx 63.5\,\mathrm{GeV}. \tag{11}$$

With the $\theta_{\rm max}$ range above, this corresponds to approximately

$$\mu \lesssim 4\times10^{-6}\ \text{to}\ 5\times10^{-2}\ \mathrm{eV} \qquad (\text{depending on } \lambda \text{ within the window}). \tag{12}$$

4 Mapping sensitivity sweep: make mapping the only dial that moves

The reviewer-proof trick is to freeze the sampled hypothesis ensemble so every mapping mode is evaluated on the same point cloud.

4.1 Deterministic point cloud

Step A: generate and save a deterministic point cloud once (store whatever the mapping needs, e.g., λ, $\alpha_{\rm eff}$, and any underlying parameters that feed $\alpha_{\rm pred}$).

4.2 Evaluation-only passes

Step B: run evaluation-only passes:

- Mode A: current placeholder mapping,
- Mode B: alternate functional dependence (not just a scale),
- Mode C: explicit scale knob $s_{\rm ff}$ multiplying a baseline mapping.

For a methods section, define mapping modes explicitly:

$$\text{A:} \quad \alpha_{\rm pred} = f_A(\theta), \tag{13}$$
$$\text{B:} \quad \alpha_{\rm pred} = f_B(\theta), \tag{14}$$
$$\text{C:} \quad \alpha_{\rm pred} = s_{\rm ff}\, f_A(\theta). \tag{15}$$

Only the mapping changes; sampled points remain identical.

4.3 Reported metrics

Step C: report per mode:

- coverage fraction (should be 1.000 in real-only mode),
- $r_{\max}$, median r, and a tail metric such as r_{95} or r_{99},
- required scale s to reach $r = 0.1$ and $r = 1$ computed from $r_{\max}$.

4.4 Conservative monotone filtering: a reviewer trap to avoid

If you apply a monotone filter to a digitized $\alpha_{\max}(\lambda)$ curve, document precisely what "conservative" means:

- If conservative means *avoid false exclusion / avoid overstating detectability*, then bias $\alpha_{\max}$ upward (since larger $\alpha_{\max}$ makes r smaller).
- A running-min on $\alpha_{\max}$ makes constraints more stringent (smaller $\alpha_{\max}$), increases r, and can create a false "closer to detectable" impression.

5 Expand real constraints into the mm–cm regime: delete the mirage properly

If the "hunt band" lived outside real λ coverage, it was not an empirical statement. The clean extension is to ingest additional *real* curves.

5.1 Curve objects and domain handling

Treat each experiment curve as an object with:

- a domain $[\lambda_{\min}, \lambda_{\max}]$,
- a defined interpolation method (log–log interpolation is typical for these plots).

5.2 Real envelope construction

Build the combined real envelope as

$$\alpha_{\max}^{\text{env}}(\lambda) = \min_i \alpha_{\max}^{(i)}(\lambda), \tag{16}$$

only where at least one curve is defined.

The coverage rule becomes:

> A real-only point is valid iff λ lies in the union of all real domains.

Include a coverage-map plot (even a shaded interval bar) so readers can see at a glance which ranges are real-supported.

6 Increase NPTS and targeted sampling: make the statistics boring

The goal is to stop fractions from wobbling and to make r-distribution summaries stable. The key is targeted sampling matched to real-only support.

Sample $\log \lambda$ from a mixture of log-uniform windows, one per real interval, optionally with a smaller broad component to capture transitions at window boundaries:

- choose a window index k according to weights (equal, or proportional to window log-width),
- sample $\log \lambda \sim \text{Uniform}(\log a_k, \log b_k)$.

Keep seeds fixed and record them (plus git commit hash) into every artifact.

7 Audit bundle: minimal "boring science UI" fields

A reviewer-proof summary output should include:

- Run metadata: date, seed, git hash, NPTS, mapping mode, real-only flag.
- Coverage: real-only coverage fraction + list of real windows used.
- Results: excluded fraction ($r > 1$), near-detectable fraction ($r > 0.1$), $r_{\max}$, r_{50}, r_{95} (or r_{99}).
- Sensitivity: $s_{0.1}$ and s_1 computed from $r_{\max}$.
- Location of max: $\lambda(r_{\max})$.

8 Licensing and permanence hygiene

Even if reviewers should not care, humans do. A mismatched LICENSE vs CITATION vs README is a low-effort doubt generator.

Clean options:

- One-license everywhere (CC0 everywhere, or CC-BY everywhere), or
- Standard research stack: code MIT/Apache-2.0; paper/docs CC-BY-4.0; data CC0 (optional).

Then ensure README + LICENSE + CITATION.cff agree.

For link permanence: GitHub Release (tagged) + attach zips as assets, then Zenodo GitHub integration to mint a DOI per release, and point CITATION.cff to the DOI.

9 Conclusion

The real-only result is a strong null outcome: under current mapping assumptions and real-only constraints, this channel does not test the model in the examined window. The next step is not to "find a signal" but to make the mapping and coverage so deterministic and honest that the conclusion becomes unavoidable: to matter here, the model-to-observable mapping must change by $\sim 10^8$.

A Optional: minimal pseudocode for a mapping sweep

Listing 1: Shape of a fixed-point mapping sweep (pseudocode).

```
# 1) Sample model points ONCE (deterministic seed)
points = sample_point_cloud(seed=SEED, npts=NPTS, real_only=True)

# 2) Evaluate-only passes: mapping modes
for mode in ["A", "B", "C"]:
    s_list = SFF_VALUES if mode == "C" else [1.0]
    for s_ff in s_list:
        r = compute_r(points, mode=mode, s_ff=s_ff)
        summarize(r) # max, tail quantiles, fractions, scaling factors
```