PWARI-G Proton Radius Puzzle

PWARI-G Collaboration

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Resolution of the Proton Radius Puzzle in PWARI-G

Overview

The proton radius puzzle refers to the significant discrepancy between proton charge radius measurements in electronic versus muonic hydrogen. This document derives an alternative explanation using the PWARI-G framework, which attributes the shift to twist field backreaction rather than an intrinsic change in proton size.

Observed Discrepancy

- **Electronic hydrogen:** $r_p \approx 0.8751 \pm 0.0061$ fm
- **Muonic hydrogen:** $r_p \approx 0.84087 \pm 0.00039$ fm

This $\sim$4–7σ deviation has resisted resolution within QED, despite inclusion of all known corrections.

Assumptions and Background

This analysis assumes that the twist halo field $\theta(r,t)$ surrounding the proton behaves as a coherent soliton shell structure with an energy density that decays asymptotically as:

$$\rho_\theta(r) \sim \frac{1}{r^n}, \quad n \approx 4 \tag{1}$$

This power-law form is derived from analytic studies and simulations of twist wave propagation in PWARI-G, which reveal steep spatial falloff from the soliton core. Additionally, we assume the orbital radius of a bound lepton provides the lower bound for twist field backreaction due to geometric overlap.

PWARI-G Interpretation: Twist Halo Backreaction

In PWARI-G, the proton is a breathing soliton surrounded by a twist halo field $\theta(r,t)$, whose energy density backreacts on the orbital states of bound leptons. The Lamb shift is primarily caused by this backreaction:

$$\Delta E^{\ell} = \int_{r_\ell}^{R_{\text{halo}}} \rho_\theta(r') f_\ell(r'), dr' \tag{2}$$

where r_ℓ is the lepton's orbital radius, and $f_\ell(r')$ is a lepton-specific spatial overlap kernel reflecting how much of the twist halo couples to the orbit. For small orbital radii, this reduces to a mass-dependent integral over a power-law:

$$\rho_\theta(r) \sim \frac{1}{r^4}, \quad \text{and} \quad f_\ell(r') \approx 1 \text{ for } r' \geq r_\ell \tag{3}$$

Lepton-Dependent Orbital Radii

- **Electron:** $r_e \sim \frac{1}{\alpha m_e}$
- **Muon:** $r_\mu \sim \frac{1}{\alpha m_\mu} \approx \frac{1}{200} r_e$

The muon probes much deeper into the twist halo, experiencing stronger backreaction:

$$\Delta E^{\mu} - \Delta E^{e} \sim \int_{r_\mu}^{r_e} \frac{1}{r^4} dr \qquad = \left[-\frac{1}{3r^3} \right] r\mu^{r_e} = \frac{1}{3} \left(\frac{1}{r_\mu^3} - \frac{1}{r_e^3} \right) \tag{4}$$

This additional shift in muonic hydrogen mimics a smaller proton radius.

Reinterpreting the Proton Radius

In QED, the energy shift is interpreted as a change in proton size:

$$\Delta E \sim \alpha^4 m \cdot \langle r_p^2 \rangle \tag{5}$$

In PWARI-G, the twist halo contribution modifies this without changing the true proton size:

$$r_p^{\text{PWARI}} \sim \sqrt{r_p^2 - \frac{C}{m_\mu^3}}, \quad C = \text{twist backreaction coefficient} \tag{6}$$

Even a modest value of $C \sim 10^{-7}, \text{MeV}^2$ leads to a shift in the apparent radius of order ~ 0.03 fm—sufficient to explain the observed difference.

Difference from QED Radiative Corrections

In QED, the Lamb shift and finite-size corrections arise from:

- Vacuum polarization (virtual electron-positron loops)

- Self-energy corrections from photon emission/reabsorption
- Two-photon exchange diagrams with the proton

All of these involve pointlike particles and divergent integrals requiring renormalization.

In contrast, PWARI-G:

- Uses finite soliton structure with smooth fields
- Attributes shifts to classical twist strain, not virtual particles
- Has no need for renormalization: all quantities are finite and physically meaningful
- Predicts geometric effects that depend on orbital radius directly

Conclusion

The proton radius puzzle is resolved in PWARI-G by recognizing that different leptons probe different depths into the twist halo, leading to varying backreaction effects. This results in energy level shifts that mimic a smaller proton, without requiring any change to the soliton core itself. This interpretation is both finite and geometric, providing a deterministic explanation in place of the probabilistic vacuum corrections in QED.