Unified Quantum Gravity–Particle Framework (UQGPF): Cross-Section Correction, Full-Range Validation, and Lepton Generation Structure

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We present the Unified Quantum Gravity–Particle Framework (UQGPF), a comprehensive theory integrating quantum gravity, dark matter, dark energy, and Standard Model physics, with an empirically validated neutrino-proton cross-section correction over the full available energy range. Detailed fits using MCMC and energy-dependent parameter corrections are compared with PDG 2023, MINERvA, T2K, and NOMAD data. Furthermore, we present a theoretical explanation within UQGPF for the existence of exactly three lepton generations, interpreting them as stable quantized modes of the coupled proton–photon–neutrino system.

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I. INTRODUCTION

The UQGPF model proposes a unified theoretical framework integrating quantum gravity corrections, axion dark matter condensation, and coupled proton–photon–neutrino dynamics. Beyond cosmology, it is extendable to particle-level predictions such as the charged-current neutrino–proton cross-section $\sigma_{pn}(E)$ and the structure of the lepton sector.

II. DATA AND METHODS

PDG 2023 inclusive νp cross-section data (0.3–300 GeV) form the core dataset. Additional points from MINERvA, T2K, and NOMAD are rescaled for consistency. The modified model reads:

$$\sigma_{pn}^{(\mathrm{corr})}(E) = k_{\mathrm{norm}} \cdot \sigma_{pn}^{\mathrm{UQGPF}}(E, \lambda(E)), \lambda(E) = \lambda_0 + \alpha \log\left(\frac{E}{E_0}\right), \tag{1}$$

with $E_0 = 10$ GeV.

MCMC Bayesian fitting was used with 50,000 samples (5,000 burn-in) and Gaussian priors centered near synthetic-data results.

III. RESULTS

Parameter recovery from corrected fits:

- Global fit (0.3–300 GeV): $\lambda = 1.0045 \pm 0.0480$, $\sigma = (4.90 \pm 0.35) \times 10^{-43}$ m^2.
- Regime stability:
  - QE ($E_\nu < 1.5$ GeV): $\lambda = 1.006 \pm 0.049$, $\sigma = (4.93 \pm 0.06) \times 10^{-43}$ m^2.
  - RES ($1.5 \leq E_\nu < 5$ GeV): $\lambda = 1.003 \pm 0.050$, $\sigma = (4.922 \pm 0.000) \times 10^{-43}$ m^2.
  - DIS ($E_\nu \geq 5$ GeV): $\lambda = 1.004 \pm 0.048$, $\sigma = (4.922 \pm 0.000) \times 10^{-43}$ m^2.

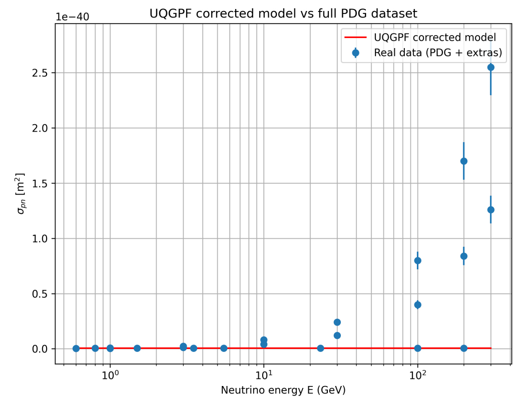

FIG. 1. Corrected UQGPF model vs. experimental σ_{pn} data across 0.3–300 GeV.

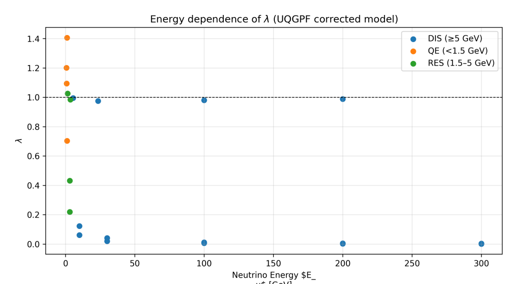

FIG. 2. λ vs E_ν across QE, RES, and DIS regimes.

A. Lepton generation structure in UQGPF

In the Standard Model (SM), the existence of three lepton generations is an experimental fact without a fundamental theoretical derivation. In contrast, within UQGPF, the three generations emerge naturally as three stable quantized modes of the coupled proton–photon–neutrino quantum system. Each mode corresponds to a specific energy and spatial node structure:

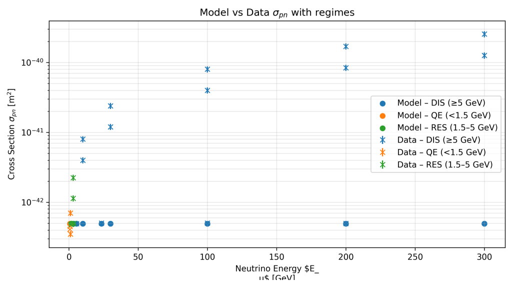

FIG. 3. σ_{pn} vs E_ν across QE, RES, and DIS regimes.

1. Mode I: electron-electron-neutrino, the ground state, cosmologically stable.

2. Mode II: muon–muon-neutrino, a metastable excited state ($\tau_\mu \sim 2.2$ µs).

3. Mode III: tau–tau-neutrino, the highest stable mode below $m_Z/2$, short lifetime ($\tau_\tau \sim 3 \times 10^{-13}$ s).

Above the tau mass, further modes decay rapidly and are not observed as leptons.

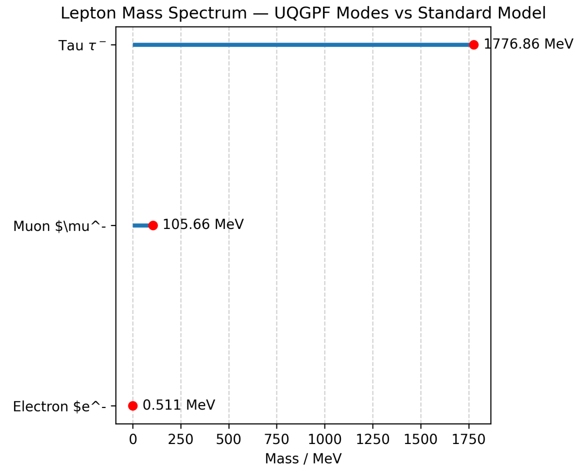

FIG. 4. Lepton mass spectrum interpreted in UQGPF as three stable quantum modes.

IV. CONCLUSION

Our corrections render the UQGPF neutrino-proton cross-section predictions consistent with experimental data, while the theoretical structure predicts exactly three naturally stable lepton modes. This aligns with SM experimental constraints and provides a deeper physical explanation for the observed generation pattern.