Contribution ID: **11** Type: **Poster**

Bridging Theory and Experiment: Quantum Gravity Phenomenology

Monday 1 December 2025 16:00 (1 hour)

Quantum gravity seeks to unify quantum mechanics and general relativity into a coherent framework, addressing fundamental questions about space-time at the Planck scale. This pursuit has inspired diverse theoretical approaches, including string theory, loop quantum gravity, causal dynamical triangulations, and emergent space-time models, each predicting distinct phenomenological signatures. On the experimental front, advancements in astrophysical observations and high-precision laboratory techniques offer opportunities to test these predictions. Potential signals include violations of Lorentz invariance, quantum space-time fluctuations, modified dispersion relations for high-energy particles, and deviations in gravitational wave propagation. This review synthesizes the current state of quantum gravity phenomenology, highlighting how theoretical insights and experimental innovations converge to constrain or reveal new physics. By integrating diverse methodologies, we aim to bridge the gap between abstract models and observable phenomena, advancing our understanding of the quantum nature of gravity.

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Session Classification: Poster Session

Track Classification: Topical Groups: Quantum Science and Technology