Precise measurements of the rare decays $K^+ \to \pi^+ \nu\bar{\nu}$ and $K_L \to \pi^0 \nu\bar{\nu}$ are essential for a deeper understanding of the mechanism of flavour mixing and CP violation. Among the many rare K- and B-decays, the $K \to \pi\nu\bar{\nu}$ modes are unique: are very sensitive to new physics (NP), being generated only at the quantum level, and their Standard Model (SM) rates can be computed to an exceptionally high degree of precision, not matched by any other flavour-changing neutral current process involving quarks.

The main reason for the exceptional theoretical cleanness of the $K \to \pi\nu\bar{\nu}$ decays is the fact that, within the SM, these processes are mediated by electroweak amplitudes of $\mathcal{O}(G_F^2)$, described by Z^0-penguins and box diagrams, which exhibit a power-like GIM mechanism. This property implies a severe suppression of non-perturbative effects, which is not present in other rare processes, such as $B \to X_s\gamma$ or non-leptonic B decays (dominated by gluon- or photon-penguin amplitudes).

A related important virtue of $K \to \pi\nu\bar{\nu}$ decays is that their clean theoretical character remains valid in essentially all extensions of the SM (again contrary to most other rare process and CP-violating observables). In all realistic scenarios these processes are generated by the same unique effective operator present in the SM. The only difference being a modified effective coupling, whose value depends only on short-distance parameters (such as masses and couplings of the new particles), and whose modulo and CP-violating phase are directly related to $\Gamma(K^+ \to \pi^+ \nu\bar{\nu})$ and $\Gamma(K_L \to \pi^0 \nu\bar{\nu})$, respectively.

The exceptional cleanness of the two decays, and their strong suppression within the SM, implies a sensitivity to new particles well above the TeV scale in realistic scenarios, such as supersymmetry or little-Higgs models. As stressed in a series of recent works, sizable non-standard effects could show up in $K \to \pi\nu\bar{\nu}$ without significant signals in B decays and, in specific scenarios, even without new particles within the LHC reach. On the other hand, if LHC will find NP in the TeV range, then the energy scale of the new degrees of freedom will be known and the measurements of the two $K \to \pi\nu\bar{\nu}$ rates will be essential in determining the flavour structure of the new theory. For instance, in models with Minimal Flavour Violation (MFV), tiny but possibly visible effects of O(10%) are expected in both channels, with a strict correlation characteristic of the MFV scenario. While larger and uncorrelated effects are possible beyond MFV. Hence a precise measurement of two channels could provide one of the best tool to confirm or disproof from data the validity of the MFV hypothesis.