WIFAI 2024 – Rare Decays

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Why rare decays?

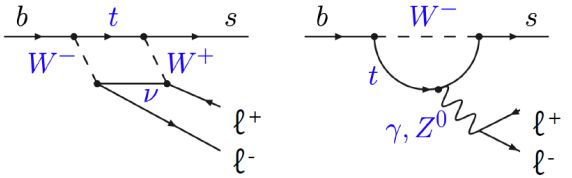
- Which are the sources of Flavour symmetry breaking we observed?
- History is telling us that rare decays are powerful tools, in particular Flavour Changing Neutral Currents (FCNC)
- Among the several accidental symmetries of the Standard Model, a particularly interesting one is the absence of tree-level FCNC
- These decays occur at loop-level, and are both GIM- and CKM-suppressed: very rare, hence fundamental probe of heavy New Physics (NP) effects
- Indeed, since no NP has been (so far) directly observed at colliders, is fundamental to have input from indirect searches where NP appears through virtual, intermediate states

- Rules of the game:
  - Precise measurements (high statistics and powerful background rejection needed)
  - Precisely predicted

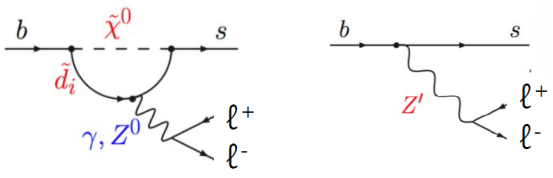
How could NP manifest? Example: $b \to s l^+ l^-$

- Modification of the decay rates (up or down)
- Modification of the angular distributions
- New sources of CP violation
- Potentially different for $l = \mu$ and $l = e$

SM

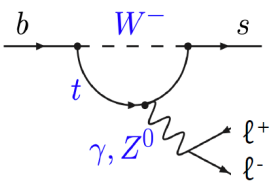


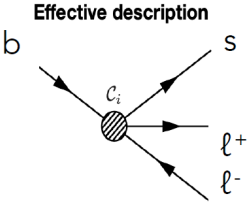
New Physics (examples)



Relative importance of the different diagrams varies with $q^2 = m^2(l^+l^-)$, e.g. photon pole dominates when $q^2 \to 0$

Theoretical description



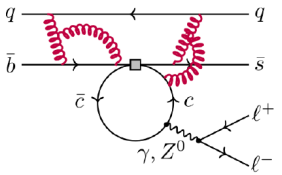


$C_7^{(\prime)}$, $C_{9,10}^{(\prime)}$

$$H_{\text{eff}} \propto V_{tb}V_{ts}^* \sum_i (C_i\mathcal{O}_i + C_i'\mathcal{O}_i')$$

$O_i^{(\prime)}$ operator encoding Lorentz structure

$$C_i^{(\prime)} = C_i^{\text{SM}\,(\prime)} + C_i^{\text{NP}\,(\prime)}$$



QCD challenges:
- working with hadrons ⇒ local form factors
- qq loops ⇒ non-local form factors + non factorizable soft gluon corrections

$$C_i^{(\prime)} = C_i^{\text{SM}\,(\prime)} + C_i^{\text{NP}\,(\prime)} + C_i^{\text{had}\,(\prime)}$$

Today's session

- Two contributions on theory:
  - Probing new physics with rare decays
  - Role of Lattice QCD for rare decays
- Status and prospects of rare decay searches at LHCb, Belle II, NA62, ATLAS/CMS
- Detector-oriented contribution:
  Evolution of trigger and TDAQ system for rare decay searches at LHCb
- Prospects for searches of rare decays in the flavor sector at future colliders