Contribution ID: **26** Type: **not specified**

General chiral structures for BNV nucleon decays and applications to hydrogen decay

Sunday, 20 April 2025 09:00 (30 minutes)

We examine the general nucleon decay interactions that involve only three light quarks without any derivatives acting on them. We identify eight generic operator structures that correspond to eight different chiral representations, $\{\mathbf{8}_{\mathtt{L}} \otimes \mathbf{1}_{\mathtt{R}}, \bar{\mathbf{3}}_{\mathtt{L}} \otimes \mathbf{3}_{\mathtt{R}}, \mathbf{6}_{\mathtt{L}} \otimes \mathbf{3}_{\mathtt{R}}, \mathbf{10}_{\mathtt{L}} \otimes \mathbf{1}_{\mathtt{R}}\backslash\}$, along with their chiral partners under the interchange of $\mathtt{L} \leftrightarrow \mathtt{R}$. The four structures, $\mathbf{8}_{\mathtt{L(R)}} \otimes \mathbf{1}_{\mathtt{R(L)}}$ and $\bar{\mathbf{3}}_{\mathtt{L(R)}} \otimes \mathbf{3}_{\mathtt{R(L)}}$, have been extensively discussed in the literature, while the remaining four are identified for the first time. We perform the chiral matching for these interactions at leading chiral order and find that there is a unique hadronic operator for each quark-level interaction. Notably, the hadronic counterparts of the new structures with $\mathbf{6}_{\mathtt{L(R)}} \otimes \mathbf{3}_{\mathtt{R(L)}}$ representations can appear at the same order as those of the four well-known ones, while those with $\mathbf{10}_{\mathtt{L(R)}} \otimes \mathbf{1}_{\mathtt{R(L)}}$ representations appear at a higher chiral order, involving derivatives of the meson octet matrix. Besides, we study BNV hydrogen decays. We employ a robust EFT approach to estimate the decay widths of two-body decays of hydrogen atom into SM particles, by utilizing the constraints on the EFT cutoff scale derived from conventional nucleon decay processes. By applying the bounds on the WCs from conventional nucleon decays, we provide a conservative estimate on hydrogen BNV decays. Our findings indicate that the bounds on the inverse partial widths of all dominant two-body decays exceed 10^{44} years. Among these modes, the least constrained diphoton decay $\mathtt{H} \to \gamma\gamma$ might be astrophysically interesting, although the monochromatic photon signal from our Sun is difficult to detect with current near-Earth telescopes.

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Session Classification: Plenary