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The role played by QCD corrections in neutrino-less double beta decay: A Summary

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Neutrinoless double beta decay ($0\nu\beta\beta$), being a lepton
number violating (LNV) process, offers an opportunity
to probe physics beyond the SM in a way complementary or maybe even unavailable for collider experiments.
Its non-observation allows to
constrain LNV beyond standard model (BSM) physics. There are two different kind of
contributions to the $0\nu\beta\beta$ amplitude: the short-range mechanisms
(SRM), which are mediated by heavy particle
exchange; and the long-range mechanisms (LRM), in
which a light neutrino is exchanged between two point-like vertices.
Here we calculate the leading order QCD corrections to both the SRM and LRM. It is shown that this QCD
corrections are
important, especially in the SRM case \cite{Gonzalez:2015ady} due the
presence of the color-mismatch effect and the corresponding mixing of
different operators, with numerically very different nuclear matrix
elements (NME). This effect leads to differences in the limits on the
Wilson Coefficients (WC) in some cases up to 3 orders of
magnitude. On the other hand, the LRM operate between two different
and distant nucleons, so that no color-mismatch appears and only QCD
vertex corrections have to be taken into account. Their effect on the
extracted limits does not exceed 60\% \cite{Arbelaez:2016zlt}, less
than the typical estimate of the uncertainties of the nuclear matrix
elements (NMEs). The impact of QCD corrections on high-scale models (HSM) can be also analysed \cite{Arbelaez:2016uto}.
In the SRM for instance, all HSM match at some scale around a $\sim$ few TeV
with the corresponding effective theory, containing a certain set of
effective dimension-9 operators. Many of these HSM receive
contributions from more than one of the basic operators and we
calculate limits on these models using the latest experimental data. \ \\
These QCD RGE results \cite{Gonzalez:2015ady,Arbelaez:2016zlt} are
valid for energy scales above $\sim$ 1 GeV - the limit of perturbative
QCD, while the typical scale of $0\nu\beta\beta$-decay is about
$\sim$ 100 MeV. In view of this fact we examine the possibility of
extrapolating the perturbative results towards sub-GeV
non-perturbative scales on the basis of the QCD coupling constant
freezing" behavior using Background Perturbation Theory \cite{Gonzalez:2017mcg}. Our
analysis suggests that such an infrared extrapolation does modify the
perturbative results for both SRM and
LRM of $0\nu\beta\beta$-decay in general only
moderately. However, out of a total of nine short-range
Wilson coefficient there is one, the tensor$\otimes$tensor effective
operator, which depends sensitively on the exact numerical value of

thefrozen" α_S. Fortunately, this operator can not appear alone in the low-energy limit of any renormalizable high-scale model. We show that all five linearly independent combinations of the scalar and tensor operators, that can appear in renormalizable models, are infrared stable.

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