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Collaborating with Martin Hirsch: Between Physics and telescopes

Juan Carlos Helo.

Large Hadron Collider probe of supersymmetric neutrinoless double beta decay mechanism

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(Dated: October 31, 2018)

In the minimal supersymmetric extension to the Standard Model, a non-zero lepton number violating coupling λ'_{111} predicts both neutrinoless double beta decay and resonant single slepton production at the LHC. We show that, in this case, if neutrinoless double beta decay is discovered in the next generation of experiments, there exist good prospects to observe single slepton production at the LHC. Neutrinoless double beta decay could otherwise result from a different source (such as a non-zero Majorana neutrino mass). Resonant single slepton production at the LHC can therefore discriminate between the λ'_{111} neutrinoless double beta decay mechanism and others.

PACS numbers: 12.60.Jy, 13.15.tg, 14.80.Ly

Heavy Sterile Neutrinos in Tau Decays and the MiniBooNE Anomaly

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(Dated: November 3, 2018)

Current results of the MiniBooNE experiment show excess events that indicate neutrino oscillations, but only if one goes beyond the standard 3 family scenario. Recently a different explanation of the events has been given, not in terms of oscillations but by the production and decay of a massive sterile neutrino with large transition magnetic moment. We study the effect of such a sterile neutrino in the rare decays $\tau^- \to \mu^-\mu^+\pi^-\nu$ and $\tau^- \to \mu^-\mu^+e^-\nu\nu$. We find that searches for these decays featuring displaced vertices between the μ^- and the other charged particles, constitute good tests for the existence of the sterile neutrino proposed to explain the MiniBooNE anomaly. These searches could be done with already existing experimental data.

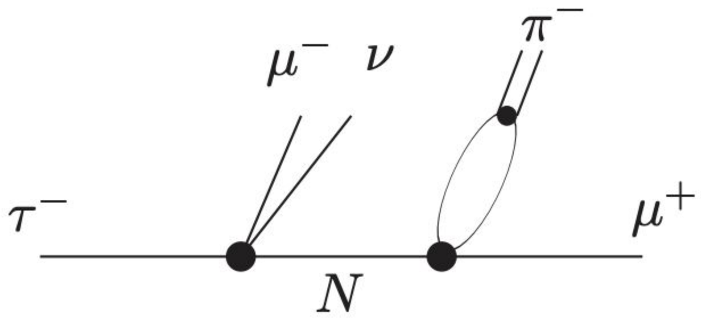
PACS numbers: 14.60.St, 13.35.Dx, 13.35.Hb, 13.15.+g, 12.15.Ji, 12.60.-i, 12.15.-y
Keywords: tau decays, sterile neutrinos, MiniBooNE, magnetic moment.

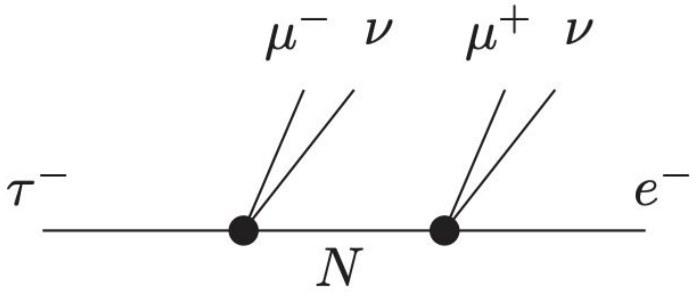
Heavy sterile neutrinos in tau decays and the MiniBooNE anomaly

S. N. Gninenko, Phys. Rev. Lett. 103, 241802 (2009)

$$400 \text{ MeV} \lesssim m_N \lesssim 600 \text{ MeV} \quad , \quad 1 \times 10^{-3} \lesssim |U_{\mu N}|^2 \lesssim 4 \times 10^{-3}$$

$$\mu_{tr} \simeq (1-6) \times 10^{-9} \mu_B \qquad 2 \times 10^{-11} \text{ s} \lesssim \tau_N \lesssim 1 \times 10^{-9} \text{ s.}$$





Dib, Kovalenko, Hirsch, Helo, Schmidt *Phys.Rev.D* 85 (2012) 011301

Neutrinoless double beta decay and lepton number violation at the LHC

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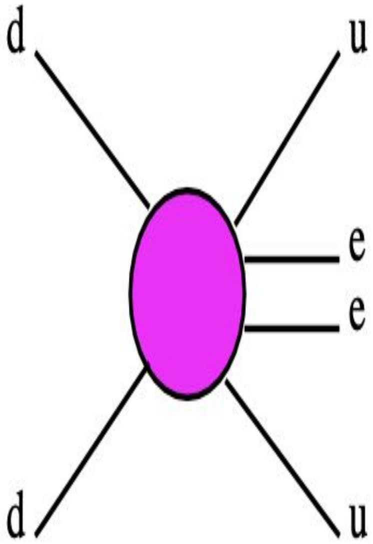
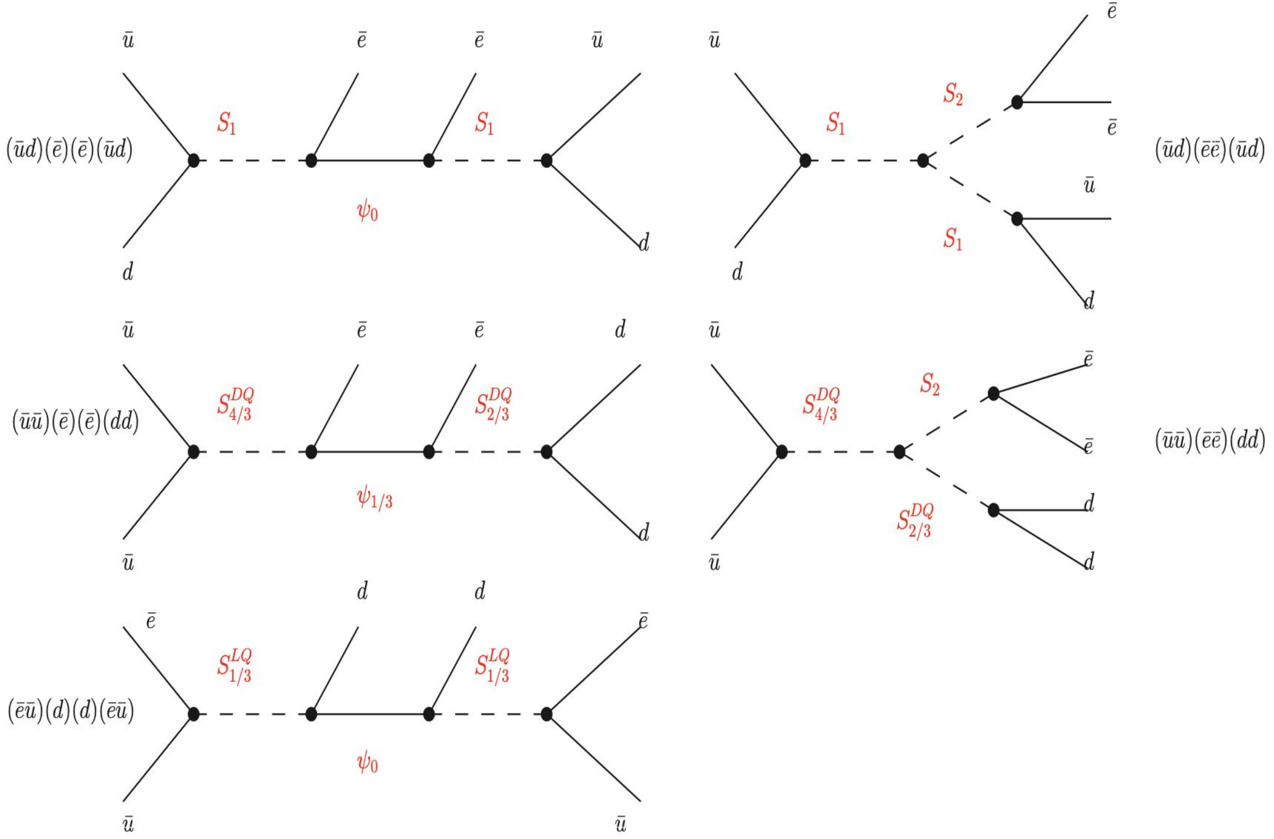
We compare the discovery potential of the LHC for lepton number violating (LNV) signals with the sensitivity of current and future double beta decay experiments, assuming $0\nu\beta\beta$ decay is dominated by heavy particle exchange. We consider charged scalar, leptoquark and diquark mechanisms of $0\nu\beta\beta$ decay, covering the $0\nu\beta\beta$ decay operators with both, the smallest and largest, possible rates. We demonstrate, if $0\nu\beta\beta$ decay were found with a half-life below $10^{26} - 10^{27}$ ys a positive signal should show up at the LHC, except for some particular cases of the leptoquark mechanism, and vice versa, if the LHC does not find any hints for LNV, a "short-range" explanation for a finite $0\nu\beta\beta$ decay half-life will be ruled out in most cases. We argue, if a positive LNV signal were found at the LHC, it is possible to identify the dominant contribution to $0\nu\beta\beta$. Two different kinds of observables which could provide such "model discriminating" power are discussed: Different invariant mass peaks and the charge asymmetry.

decomposition of the d=9 double beta decay operator





18 decompositions in total

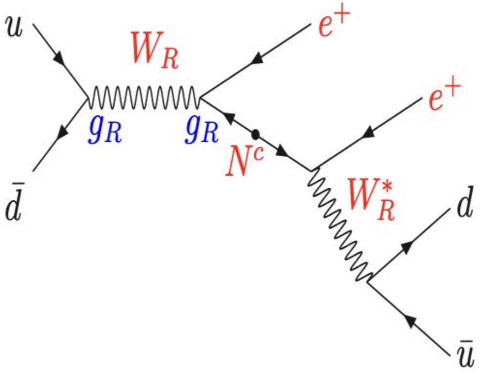
× SFS, VFS and VFV

× # of different chirality insertions P_L and P_R

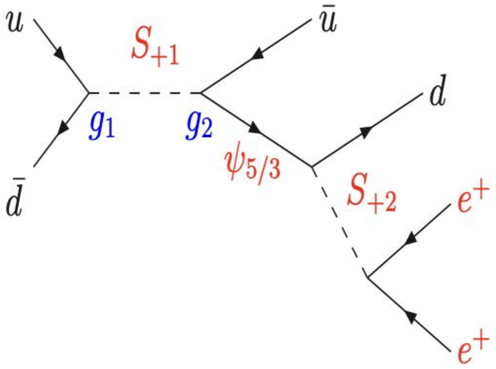
F. Bonnet, M. Hirsch, T. Ota, W. Winter, JHEP03 (2013) 055; arXiv:1212.3045

Neutrinoless and double beta decay at the LHC

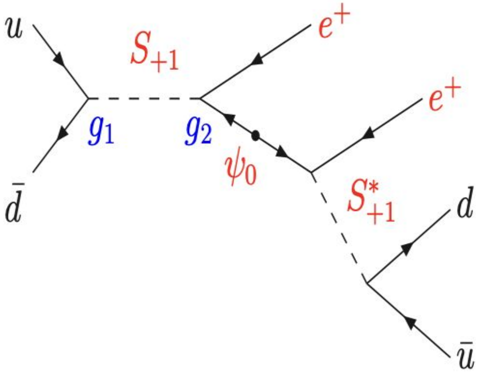
Phys.Rev.D 88 (2013) 1, 011901, *Phys.Rev.D* 88 (2013) 073011



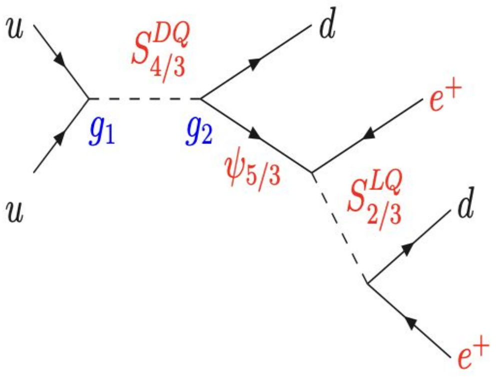
$$p^2_{eejj} = m^2_{W_R}$$
$$p^2_{e_2jj} = m^2_N$$



$$p^2_{eejj} = m^2_{S_{+1}}$$
$$p^2_{eej_2} = m^2_{\psi_{5/3}}$$
$$p^2_{ee} = m^2_{S_{+2}}$$

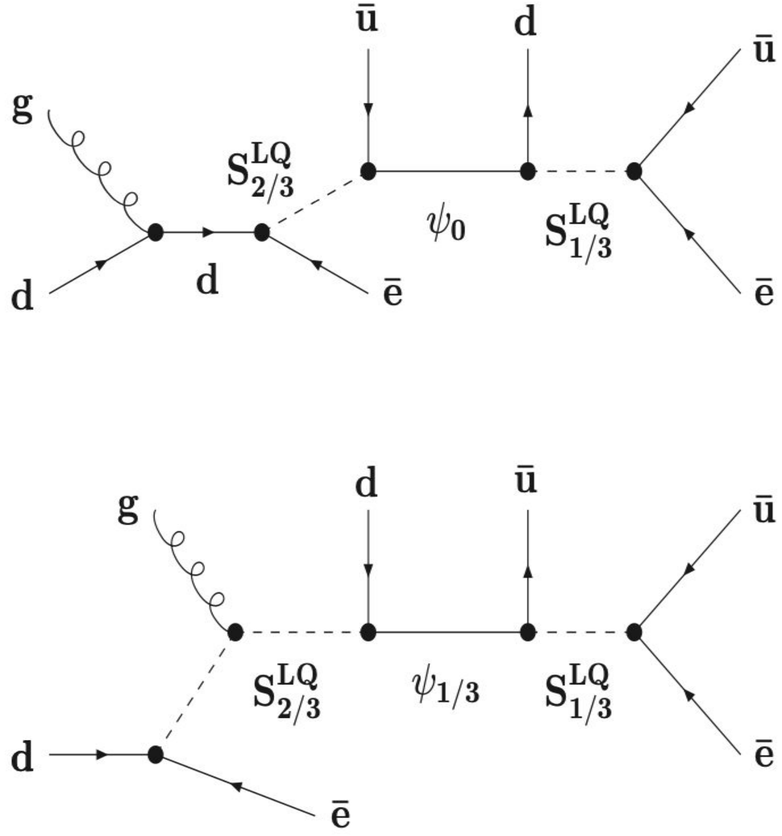


$$p^2_{eejj} = m^2_{S_{+1}}$$
$$p^2_{e_2jj} = m^2_{\psi_0}$$



$$p^2_{eejj} = m^2_{S^{DQ}_{4/3}}$$
$$p^2_{eej_2} = m^2_{\psi_{5/3}}$$
$$p^2_{e_2j_2} = m^2_{S^{LQ}_{2/3}}$$

Neutrinoless and double beta decay at the LHC



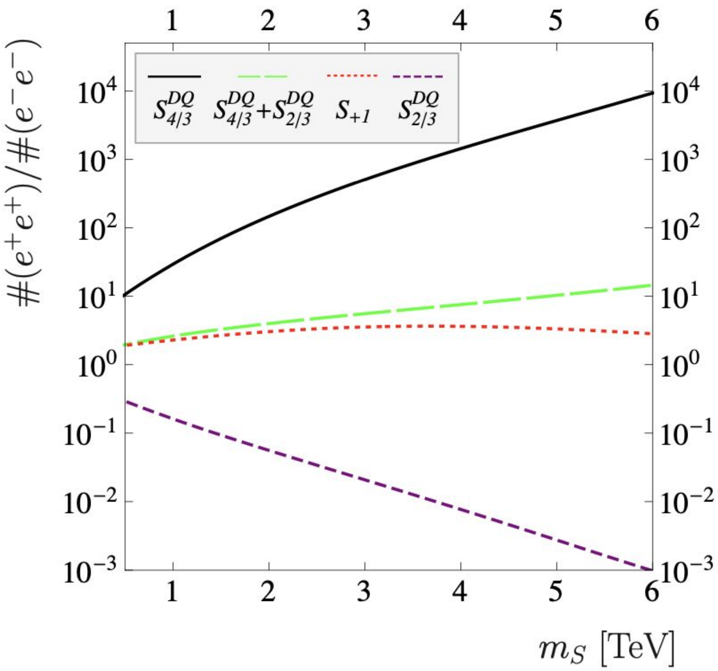
Only example!

No peak in p^2_{eejj}!

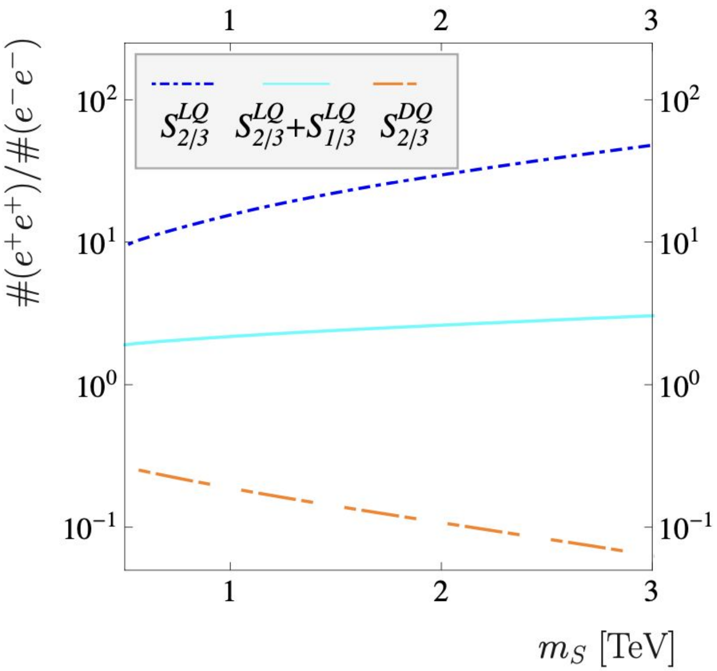
$$p^2_{ejjj} = m^2_{S^{LQ}_{2/3}}$$
$$p^2_{ej_2j_3} = m^2_{\psi}$$
$$p^2_{ej_3} = m^2_{S^{LQ}_{1/3}}$$

Neutrinoless and double beta decay at the LHC

Diquark (and S_{+1}) cases:



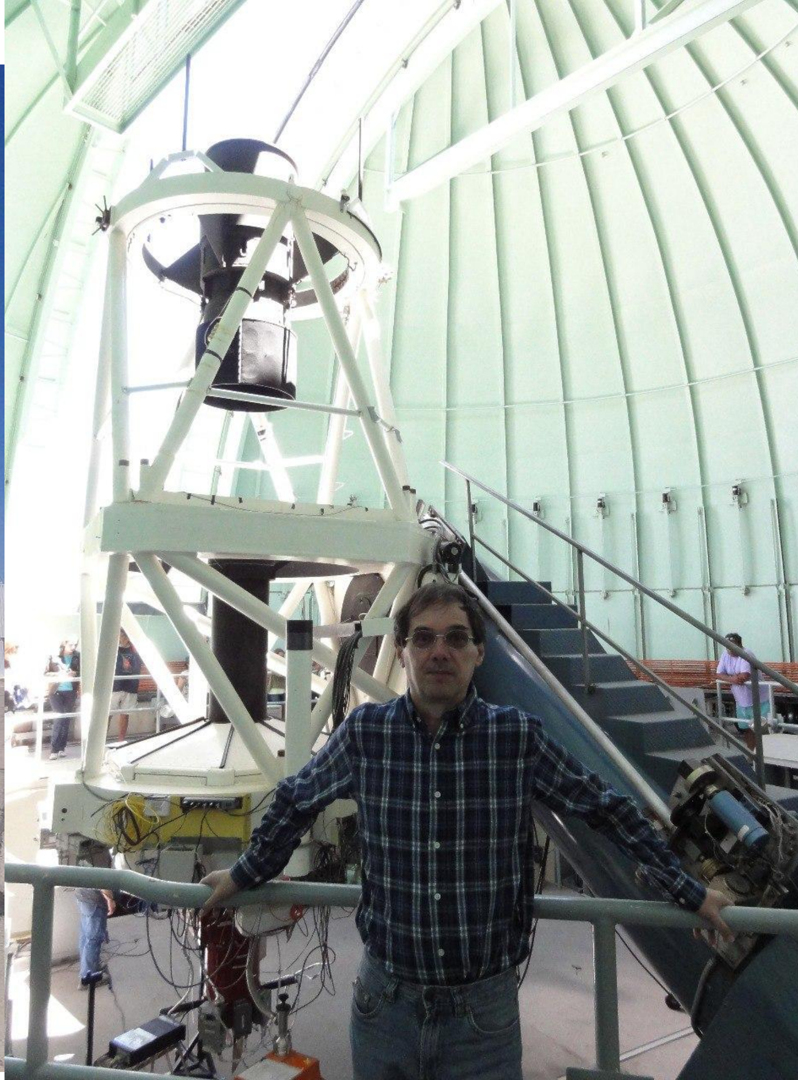
Leptoquark cases:



$\Rightarrow$ (red) S_{+1} like LR-symmetric model: $x_{CA} \simeq [2.3.5]$

$\Rightarrow$ x_{CA} can be very different in general case!

January 2014: Cerro Tololo



Heavy neutrino searches at the LHC with displaced vertices

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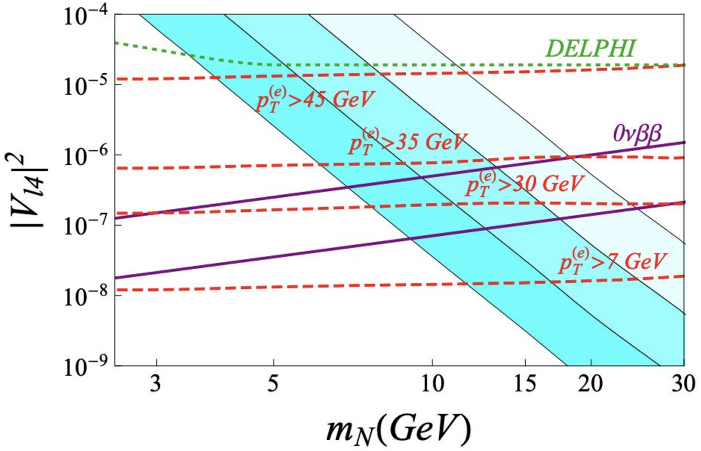
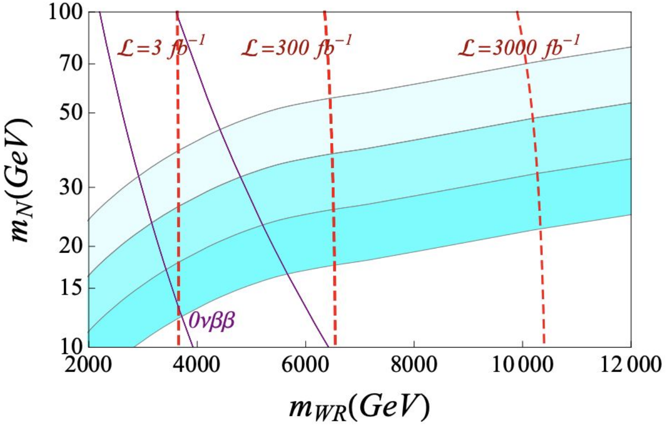
Sterile neutrinos with masses in the range (1-100) GeV, have been searched for in a variety of experiments. Here, we discuss the prospects to search for sterile neutrinos at the LHC using displaced vertices. Two different cases are discussed: (i) the standard model extended with sterile neutrinos and (ii) right-handed neutrinos in a left-right symmetric extension of the standard model. A dedicated displaced vertex search will allow to probe parts of the parameter space not accessible to other searches, but will require large luminosity in both cases.

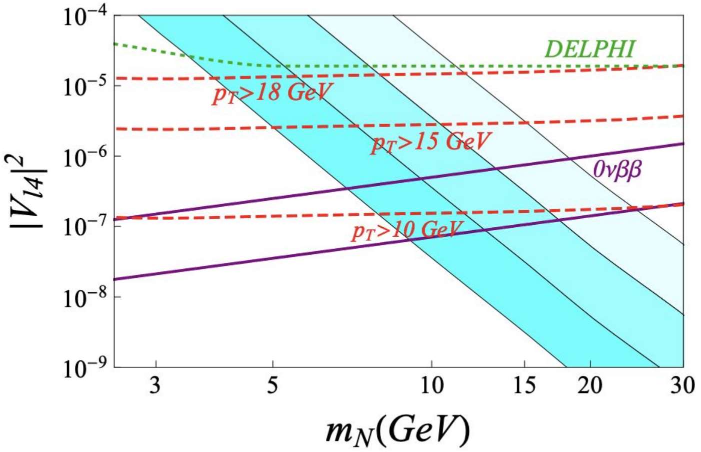
Keywords: neutrino masses and mixing; LHC

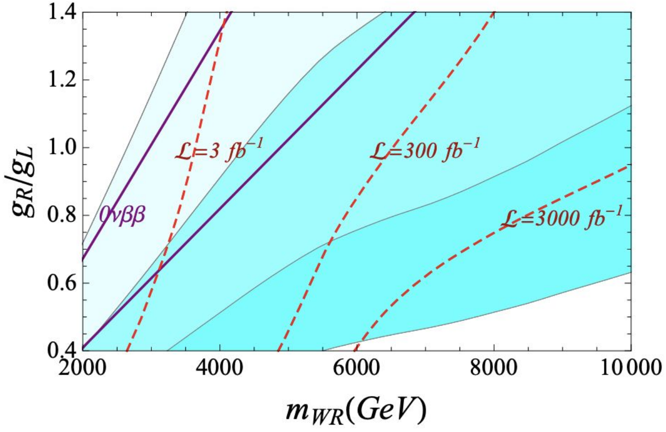
Heavy neutrino searches at the LHC with displaced vertices

Phys. Rev. D **89**, 073005









January 2015: Magellan and Geminis.

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Double beta decay and neutrino mass models

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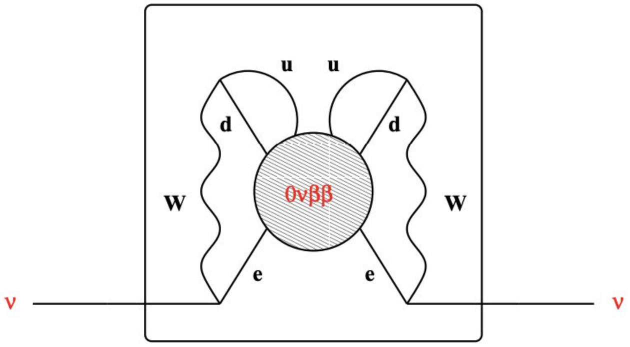
Double beta decay and neutrino mass models

JHEP 05 (2015) 092, *JHEP* 06 (2016) 006



J. Schechter and J.W.F. Valle, Phys.Rev. D 25, 2951 (1982);

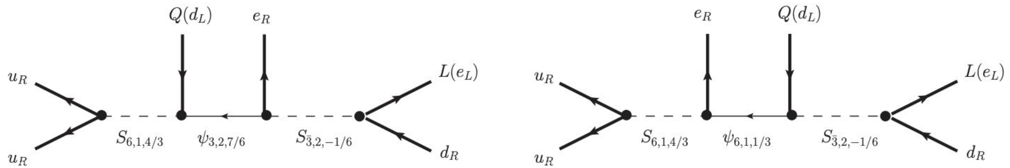


FIG. 8: The Feynman diagrams for the decompositions T-I-4-ii-a (left) and T-I-4-ii-b (right) for BL operator $\mathcal{O}_{20}$. The former leads to 2-loop $d = 7$ neutrino masses, while the latter is an example of a 3-loop neutrino mass model, see text.

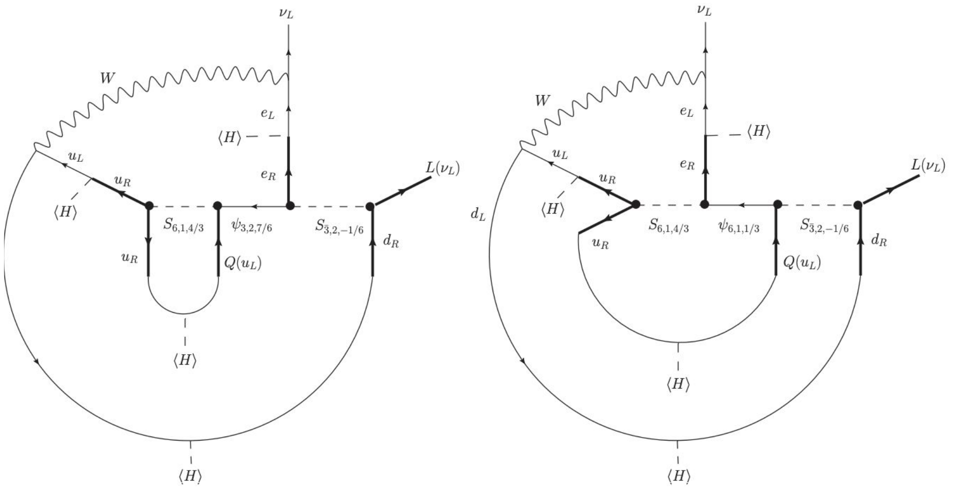


FIG. 9: Examples of 3-loop diagrams for the decompositions T-I-4-ii-a (left) and T-I-4-ii-b (right) for BL operator $\mathcal{O}_{20}$, see Fig. 8. The diagram to the right corresponds to a genuine 3-loop model, while the one to the left is not. See text.

January 2016: VLT, paranal.





January 2023: Vera rubin.

Multitasking Martin.

January 2030?: ELT, the Extremely Large Telescope.