$0\nu\beta\beta$ within the Left- Right Symmetric Model

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Supervised by Prof. Allanach

2-11-2015 IPPP Student Seminar

Outline

- Neutrino masses and seesaw mechanism

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- Experimental signatures of $0\nu\beta\beta$

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- Experimental signatures of $0\nu\beta\beta$
- Standard mechanism for $0\nu\beta\beta$
- Minimal Left-Right Symmetric Model (LRSM)
- Extra contributions to $0\nu\beta\beta$ and limits on new physics parameters

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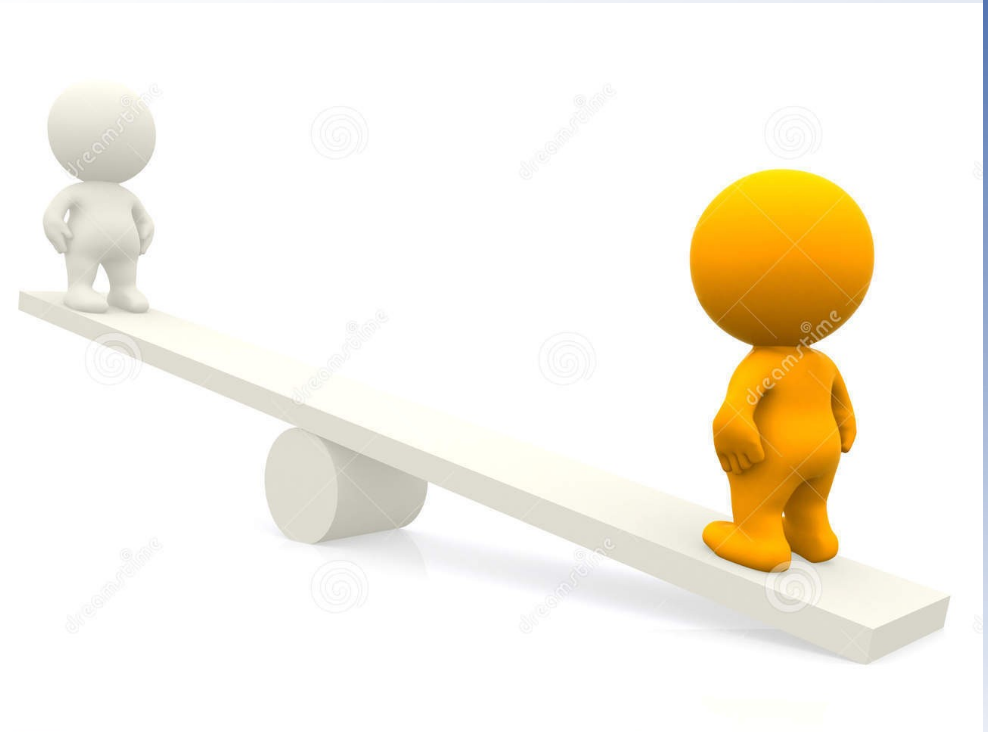

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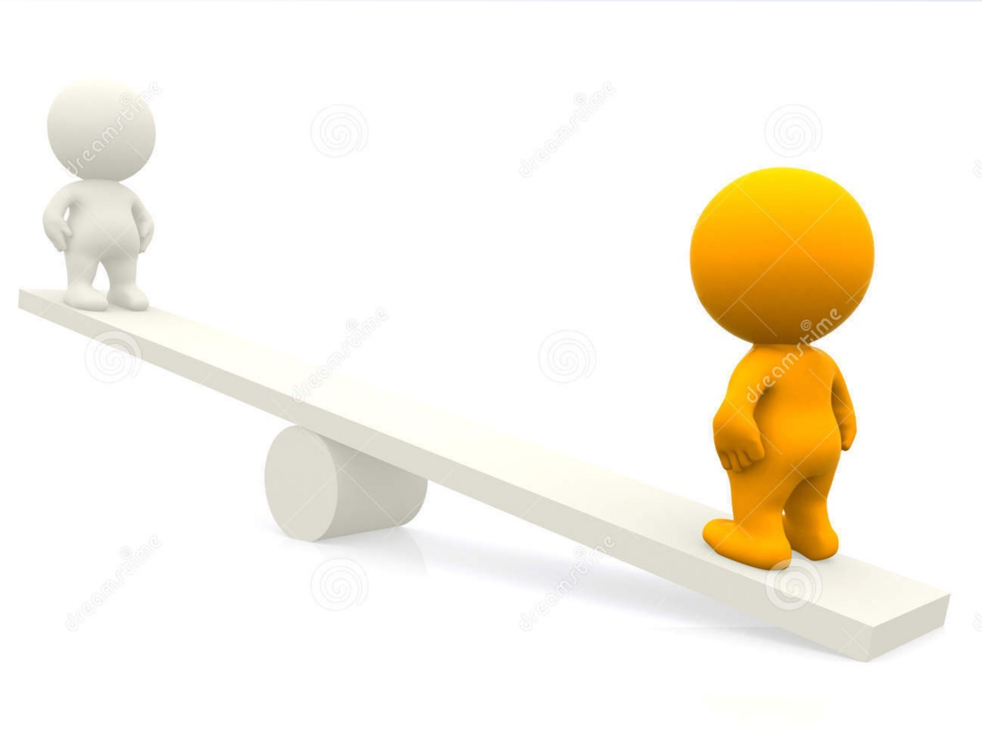

- Type I: Adding heavy right handed neutrinos N
- Type II: Adding a scalar triplet Δ
- Type III: Adding a fermionic triplet

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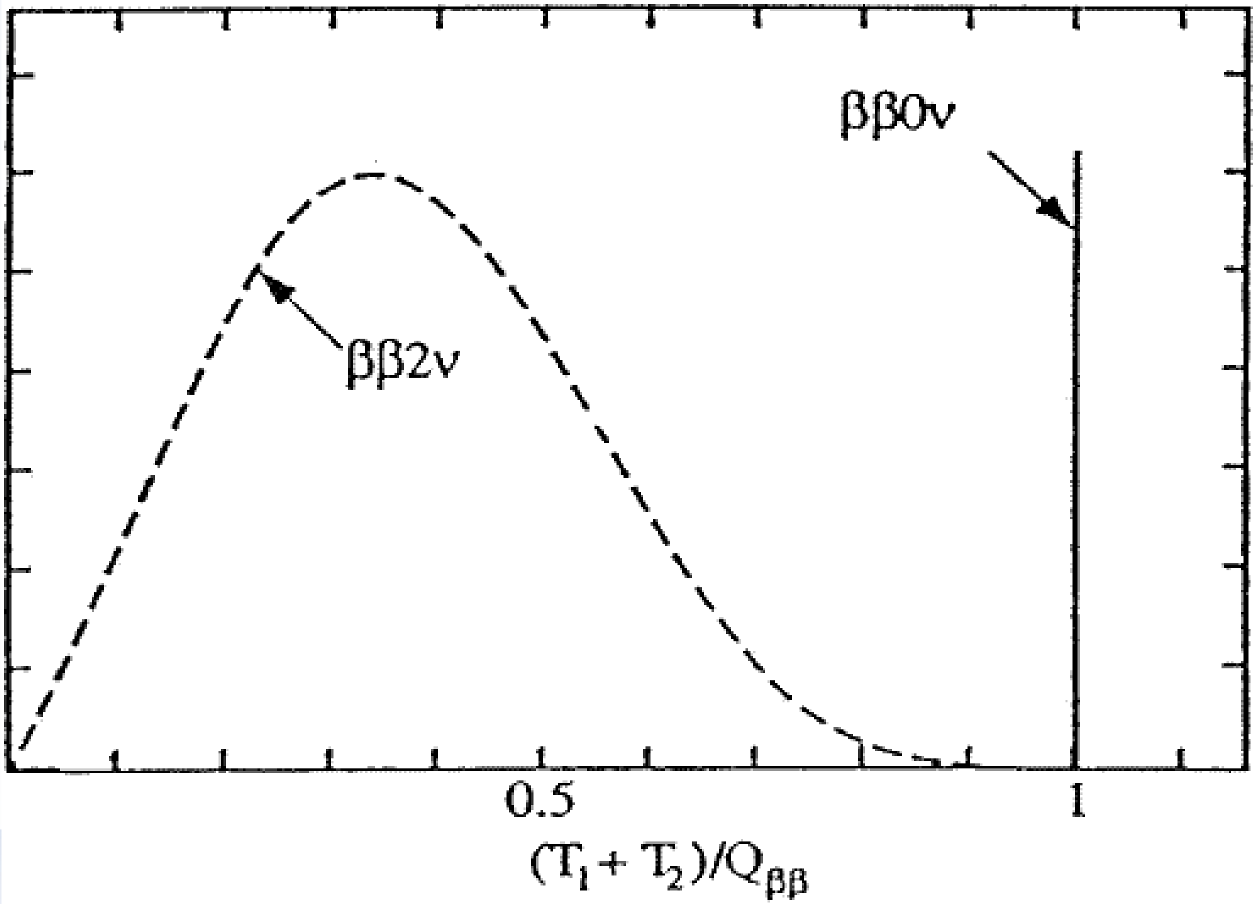

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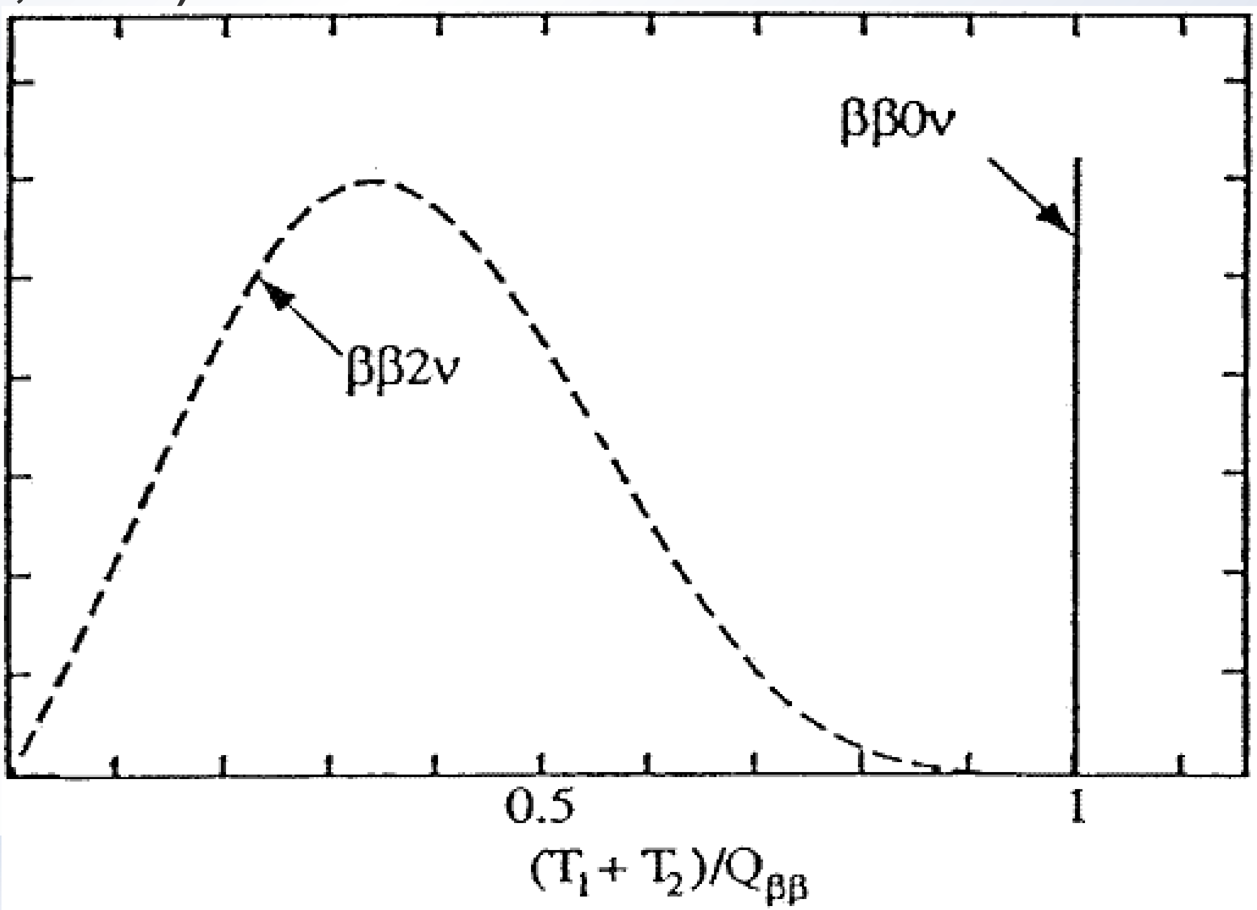

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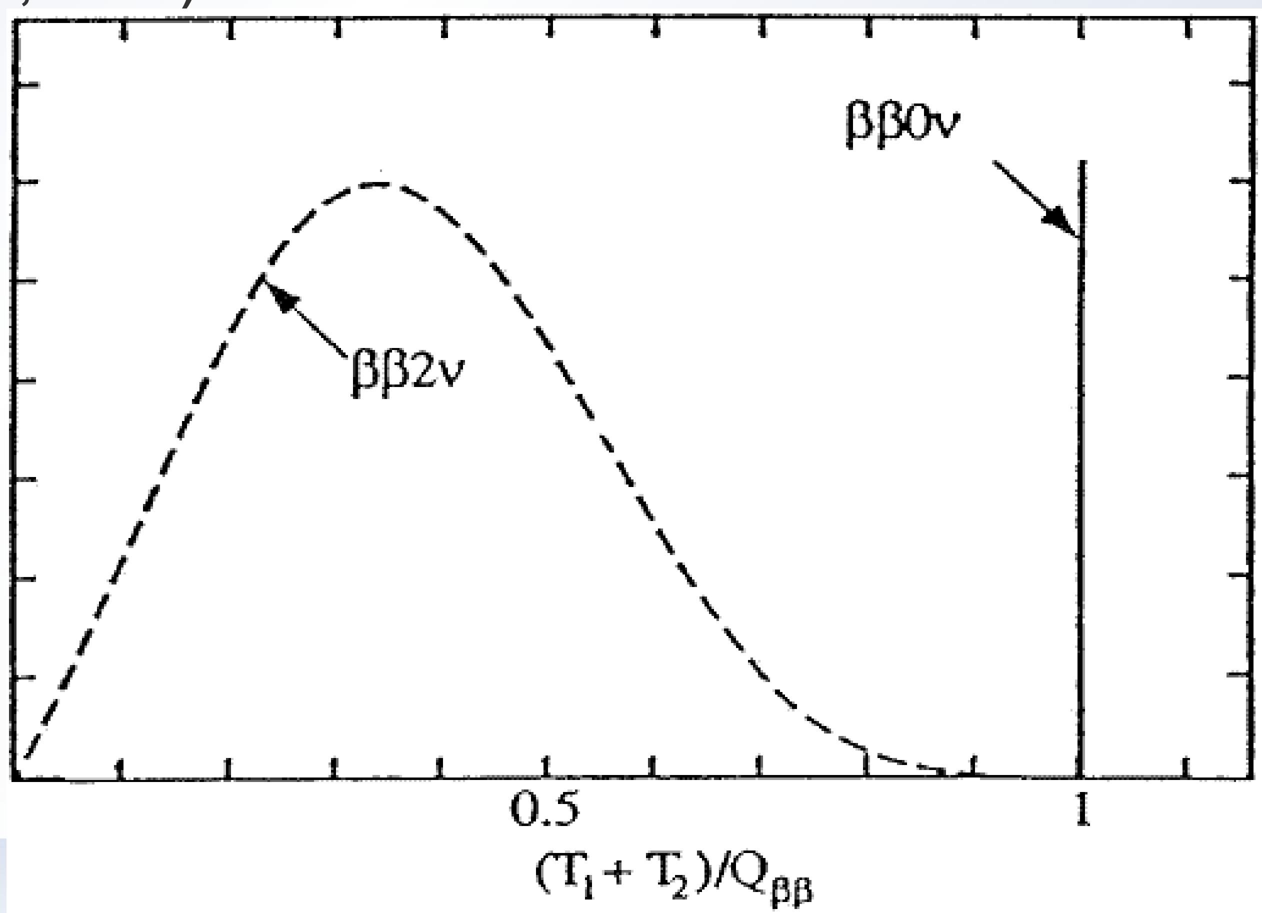
- Decay of ^{76}Ge and ^{136}Xe



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- Many experiments looking at this process: Gerda, Heidelberg-Moscow, IGEX, Exo, KamLand-Zen
  - $T_{1/2}$ for $^{76}Ge = 3.0 \times 10^{25}$ Yrs
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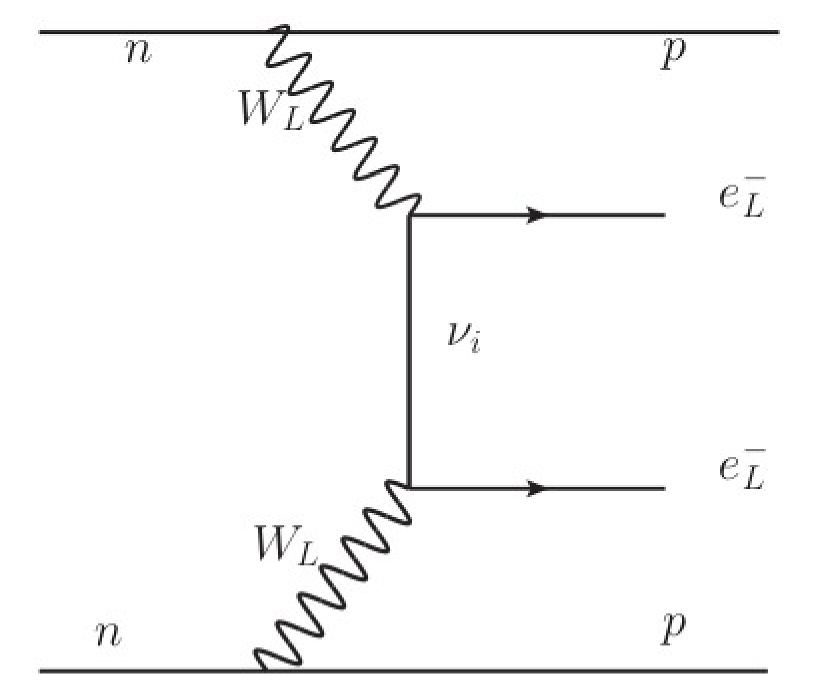
Phase Space Factor — Nuclear Matrix Element

- $\eta_x \propto$ Amplitude of different processes

Standard 0νββ

- Light neutrino exchange



arXiv:1204.2527

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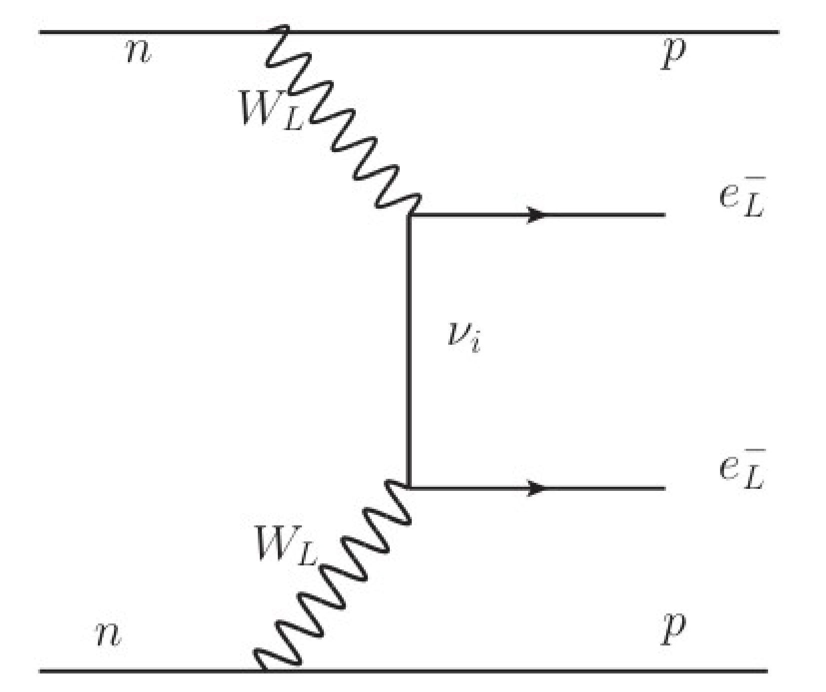

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$$\mathcal{A}_\nu = \sum_i^3 G_F^2 U_{ei}^2 \frac{m_i}{q^2 - m_i^2} \approx \sum_i^3 G_F^2 U_{ei}^2 \frac{m_i}{q^2} \propto \frac{m_\nu^{ee}}{q^2}$$

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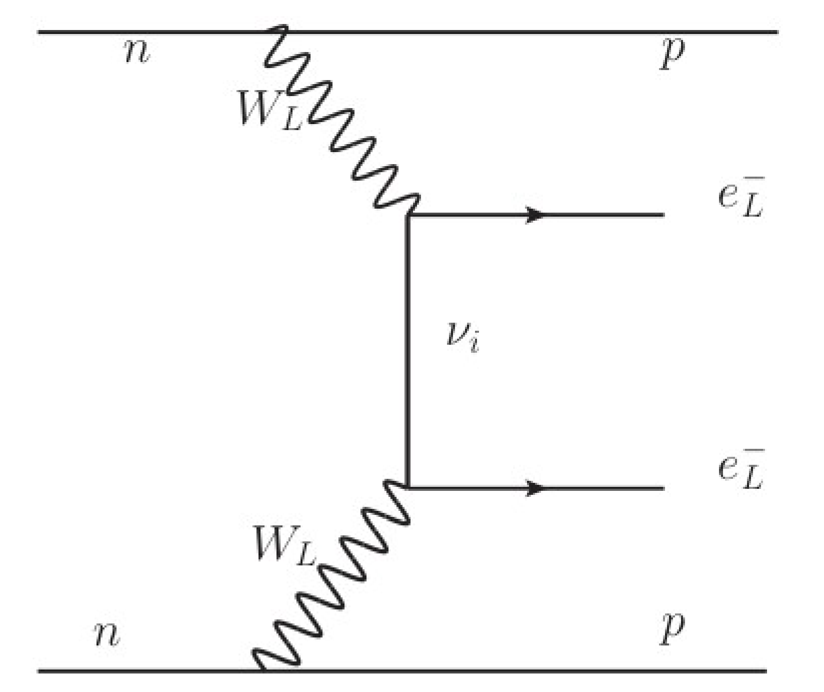

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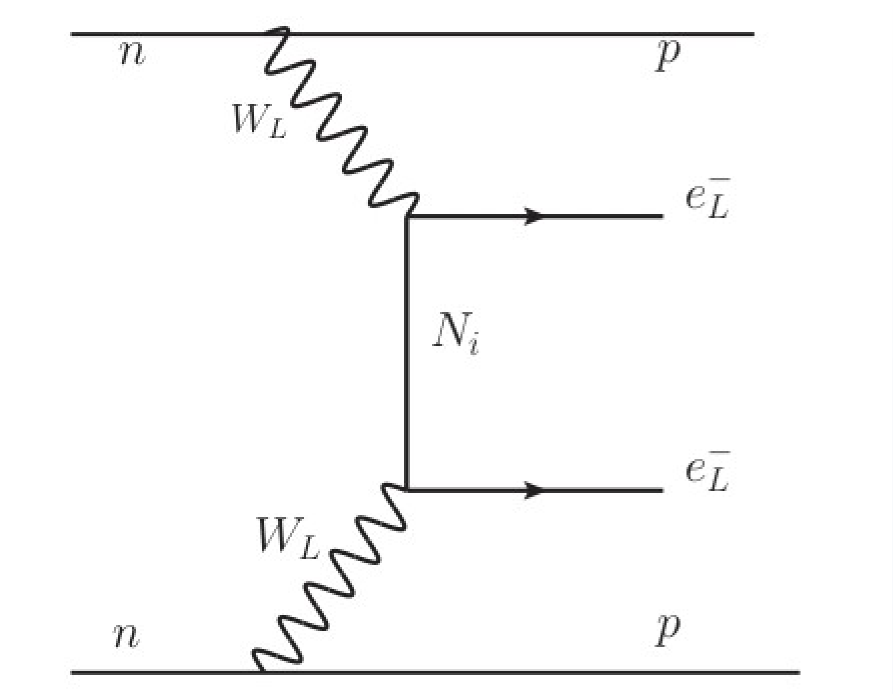
For q≈100 MeV ≫ m_i

Heavy neutrino exchange



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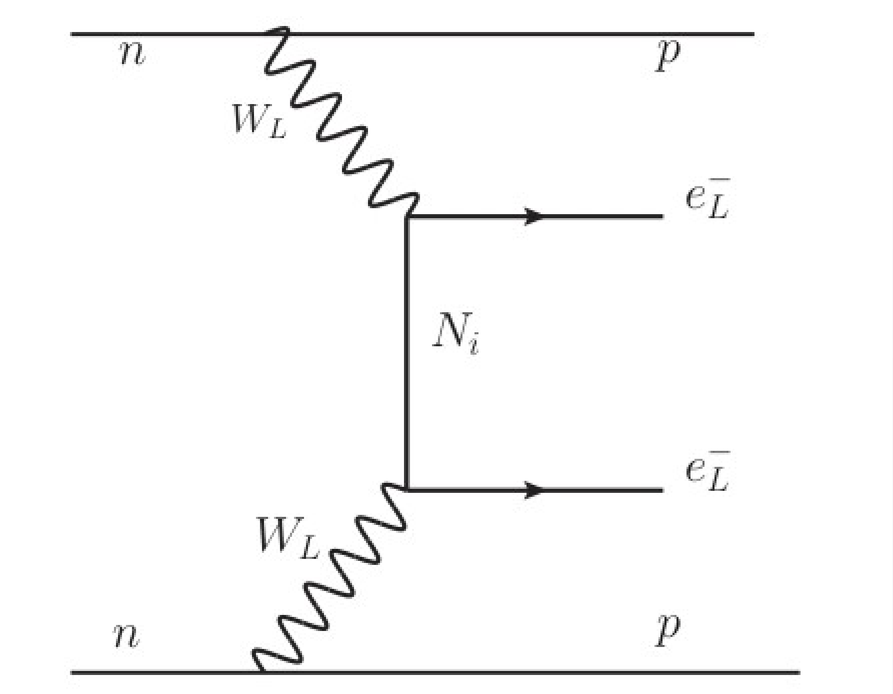

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$$\mathcal{A}_N = \sum_i^3 G_F^2 T_{ei}^2 \frac{M_i}{q^2 - M_i^2} \approx \sum_i^3 G_F^2 T_{ei}^2 \frac{1}{M_i} \propto \frac{1}{m_N^{ee}}$$

Assuming $M_i \gg q$

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- Theoretical: Can be embedded in GUT models like SO(10)
- Will introduce new channels that contribute to $0\nu\beta\beta$

Left-Right Symmetric Model

$$\mathrm{SU}(2)_L \times U(1)_Y \to SU(2)_L \times SU(2)_R \times U(1)_{B-L}$$

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Δ_L	$\begin{pmatrix} \frac{\Delta_L^+}{\sqrt{2}} & \Delta_L^{++} \\ \Delta_L^0 & \frac{-\Delta_L^+}{\sqrt{2}} \end{pmatrix}$	3	1	2
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Extended Lagrangian

$$\mathcal{L}_Y = h_1\bar{\psi}_L\phi\psi_R + h_2\bar{\psi}_L\widetilde{\phi}\psi_R + h_3\bar{Q}_L\phi Q_R + h_4\bar{Q}_L\widetilde{\phi}Q_R + \\ + i\,h_5\psi_L^T C\sigma_2\Delta_L\psi_L + i\,h_6\psi_R^T C\sigma_2\Delta_R\psi_R + h.c.$$

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- Symmetry breaking occurs in two steps and $\langle \Delta_R \rangle \gg \langle \Delta_L \rangle$

$$\phi = \begin{pmatrix} k_1 & 0 \\ 0 & k_2 \end{pmatrix}, \quad \Delta_{L,R} = \begin{pmatrix} 0 & 0 \\ \kappa_{L,R} & 0 \end{pmatrix}$$

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$$m_N = h_6 \kappa_R$$

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$$\kappa_R \gg k_1 \gg \kappa_L$$

$$\mathrm{h}_1 k_1 \gg h_2 k_2$$

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New contributions to 0νββ

- Light and heavy neutrino exchange with two W_R bosons

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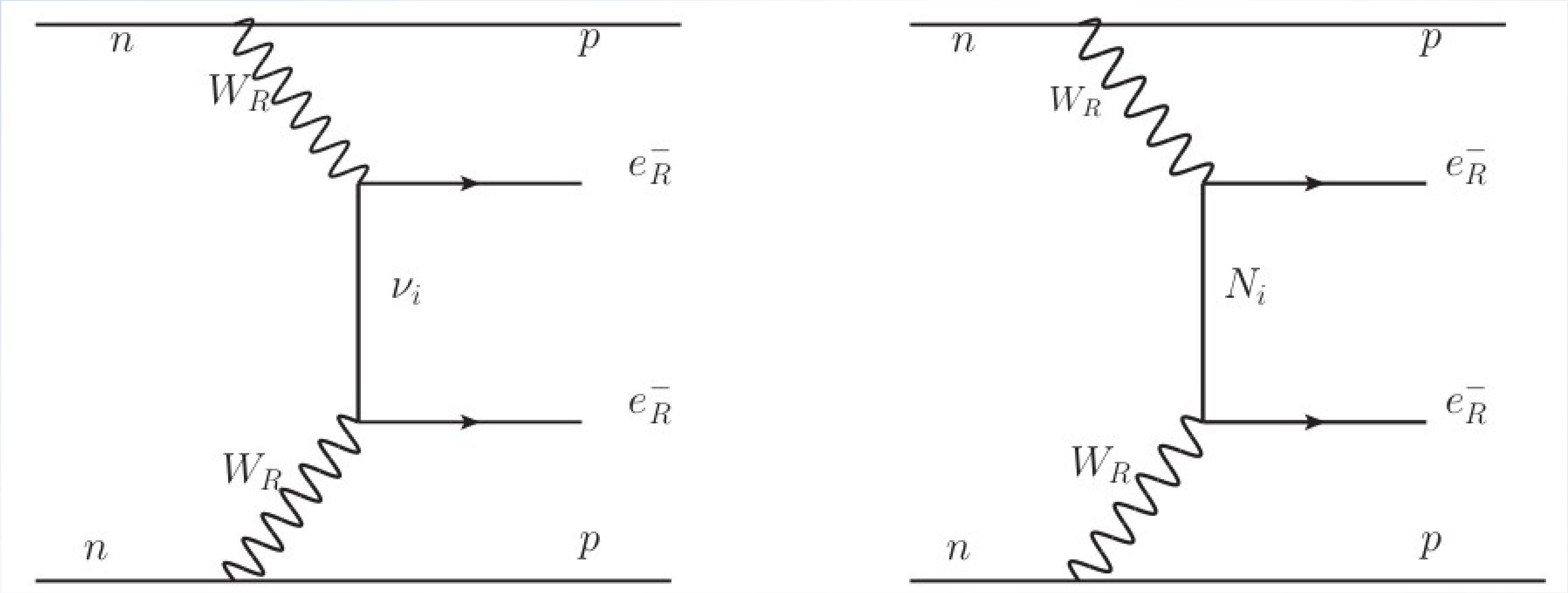

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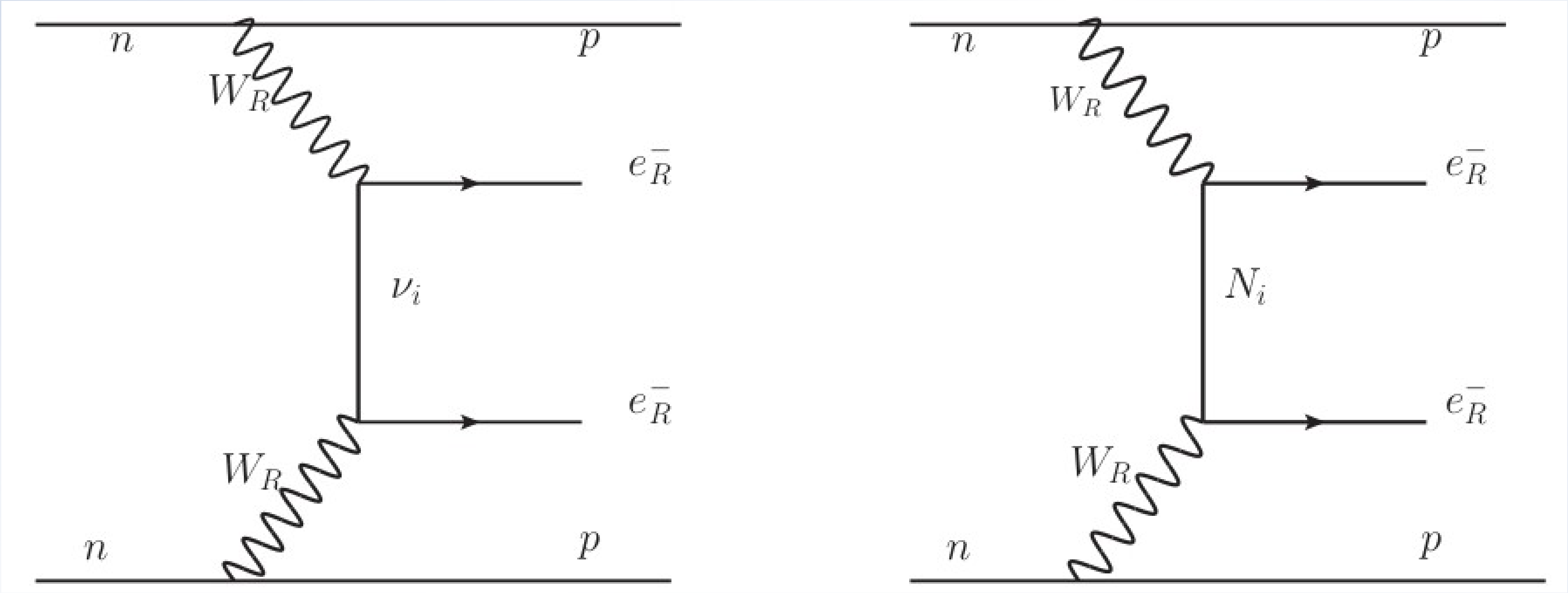

$$A_\nu^{RR} \propto G_F^2 \frac{M_{W_L}^4}{M_{W_R}^4} \sum_i^3 \frac{(S^*)_{ei}^2 m_i}{q^2}$$

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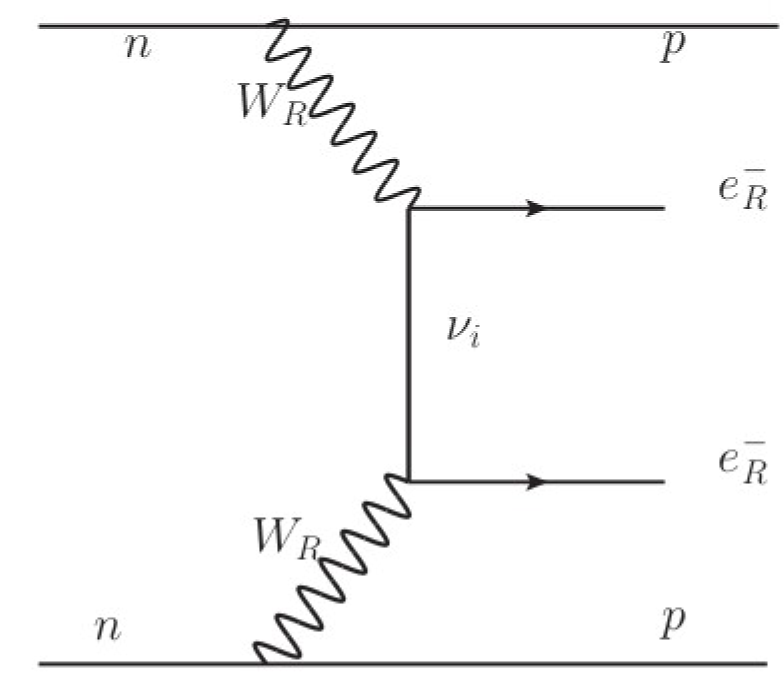
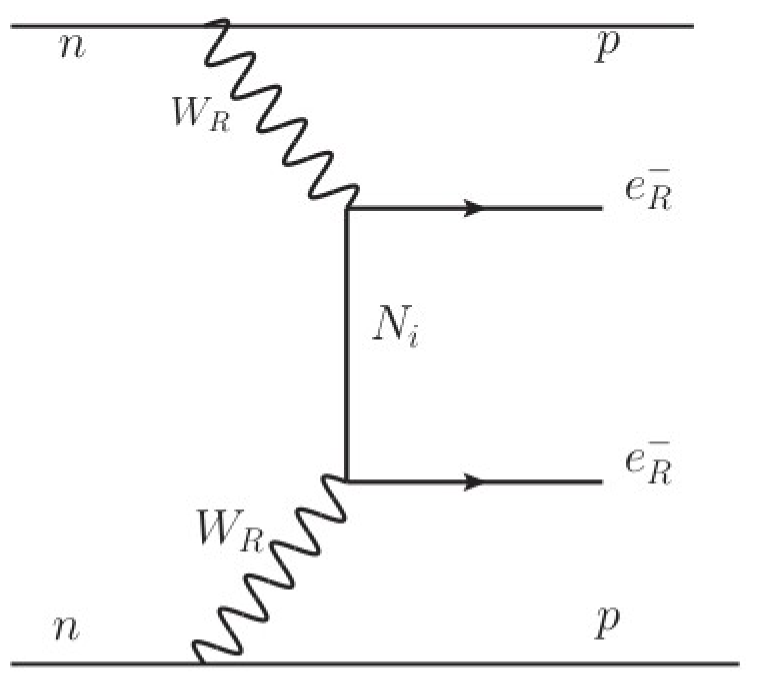




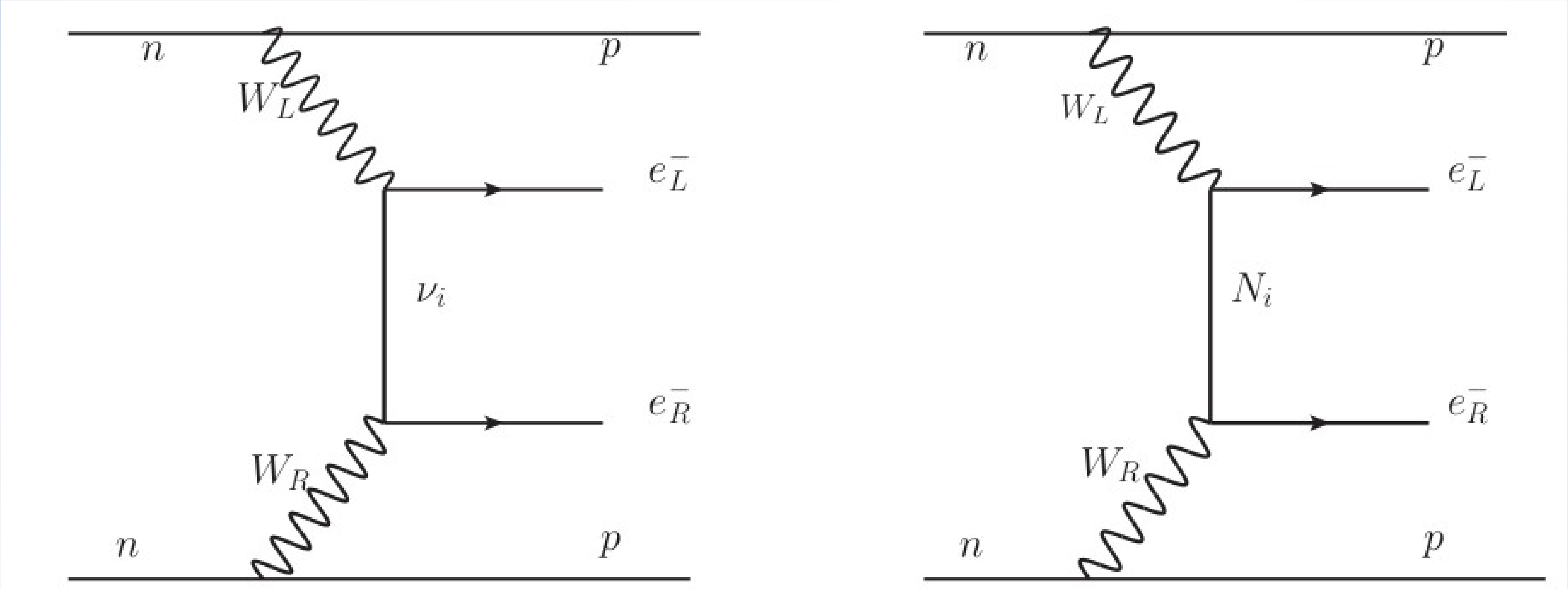
$$A_\nu^{RR} \propto G_F^2 \frac{M_{W_L}^4}{M_{W_R}^4} \sum_i^3 \frac{(S^*)_{ei}^2 m_i}{q^2}$$

$$A_N^{RR} \propto G_F^2 \frac{M_{W_L}^4}{M_{W_R}^4} \sum_i^3 \frac{(U_R^*)_{ei}^2}{M_i}$$

Amplitudes II

- W_L and W_R exchange

arXiv:1204.2527



Amplitudes II

- W_L and W_R exchange

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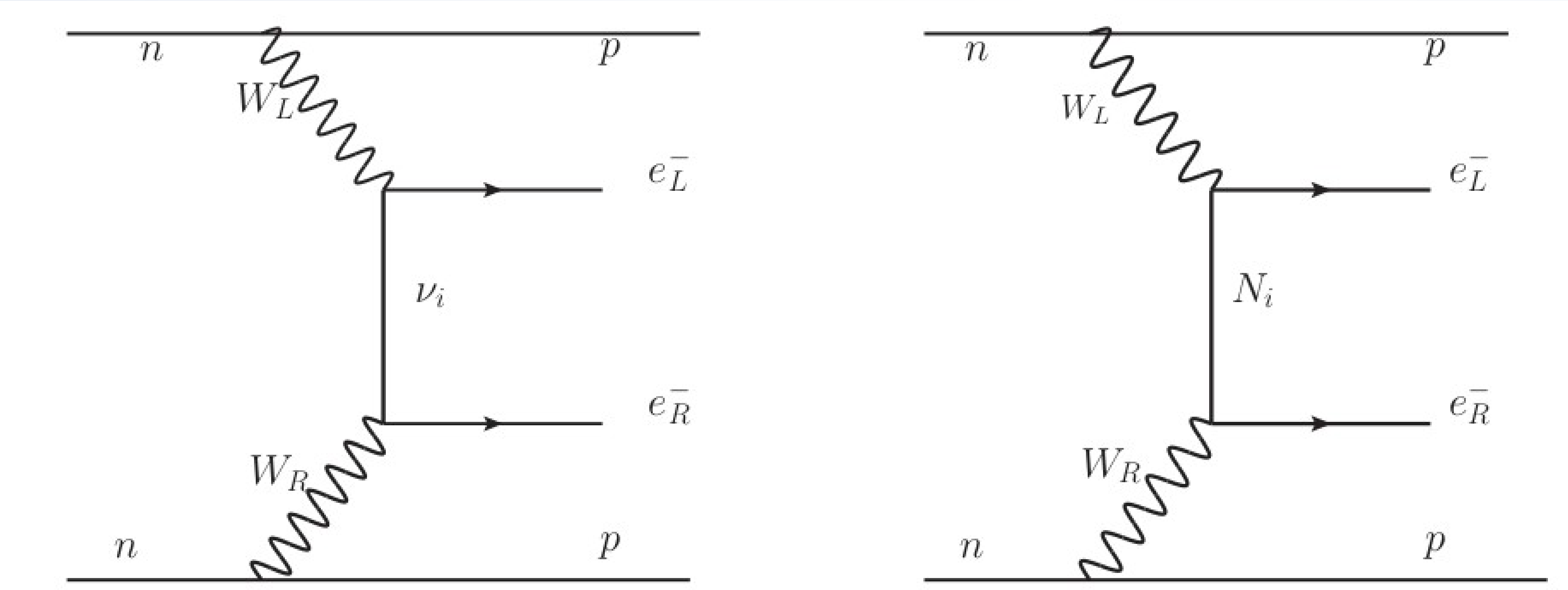

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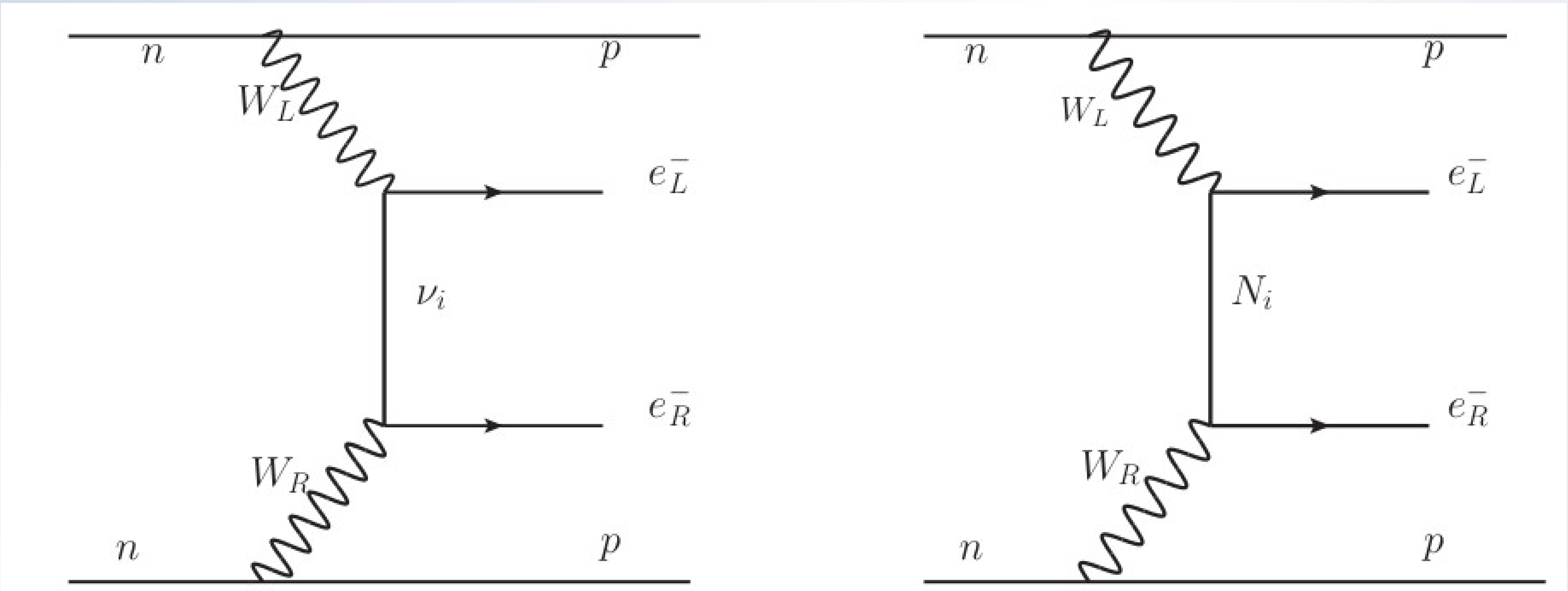

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Amplitudes III

- Δ^{--}_L and Δ^{--}_R exchange

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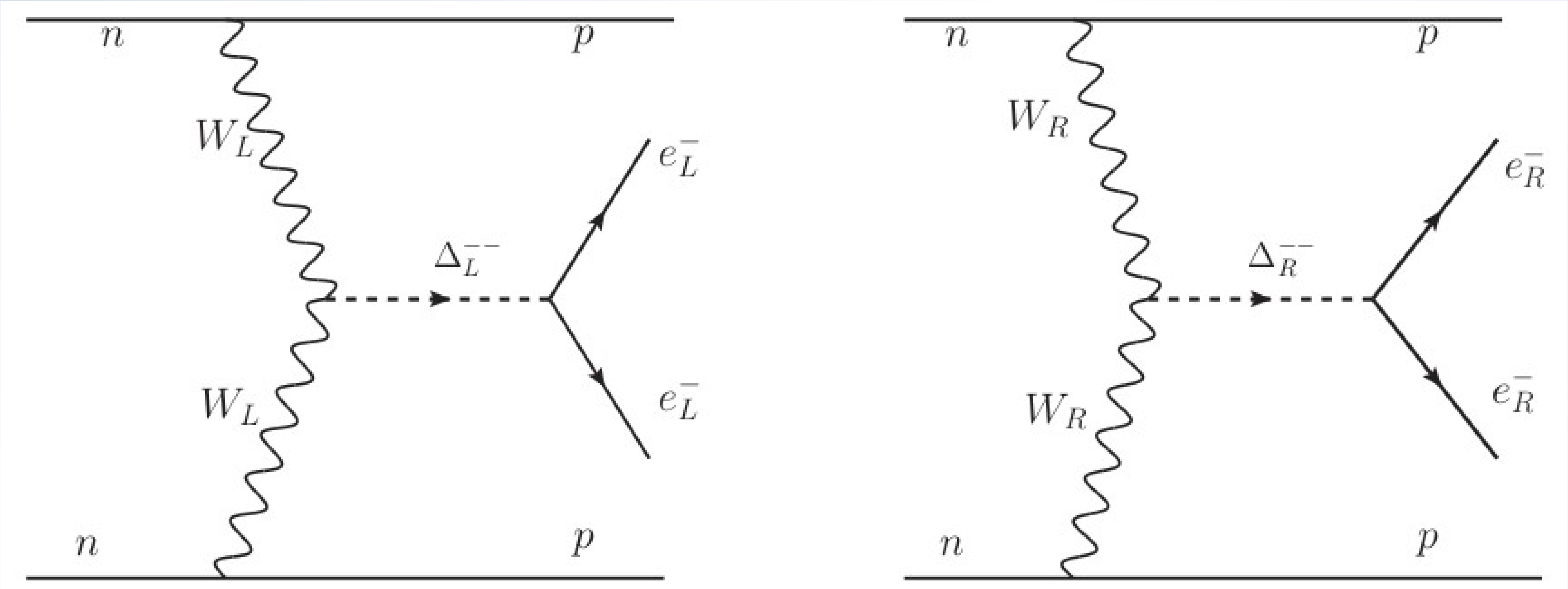

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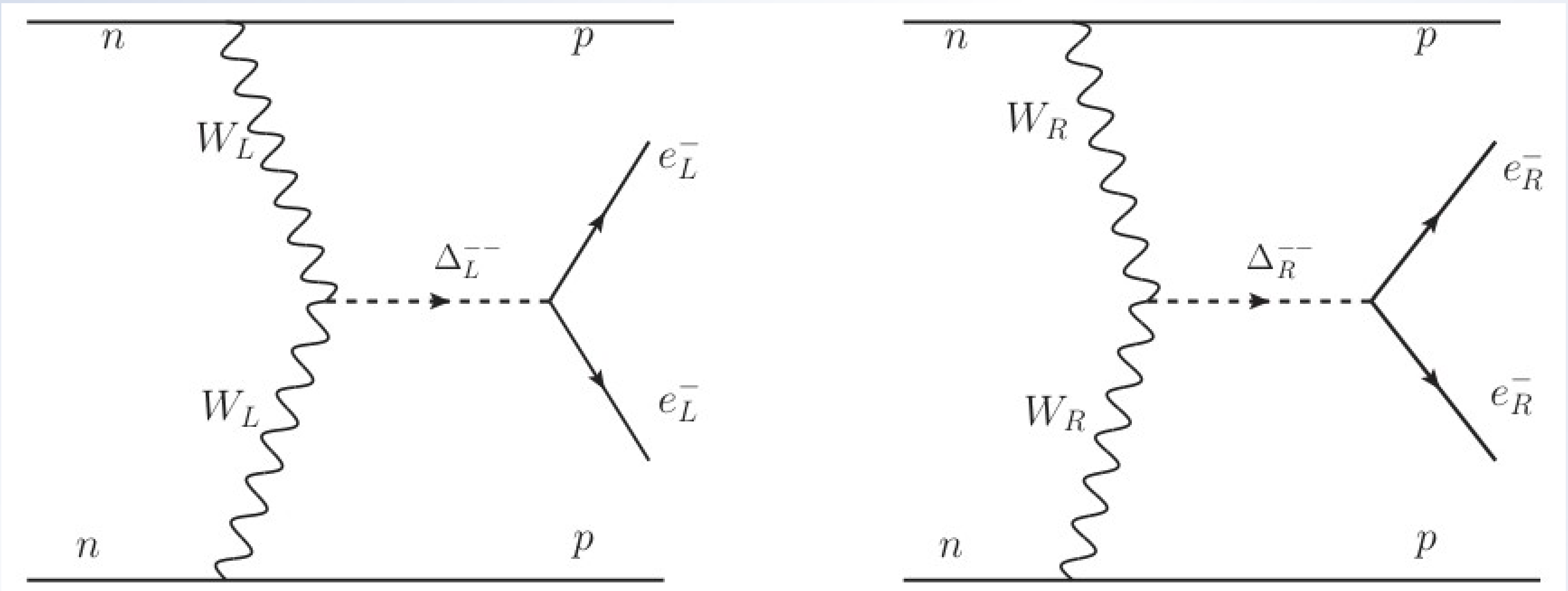

$$A^{LL}_{\Delta_L} \propto G_F^2 \sum_i^3 \frac{(U_L)^2_{ei} m_i}{M^2_{\Delta_L}}$$

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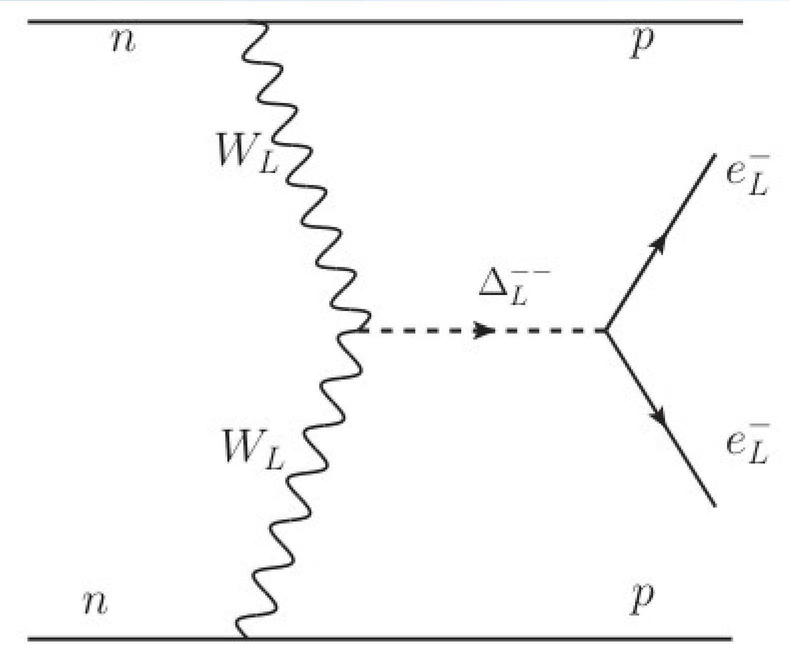

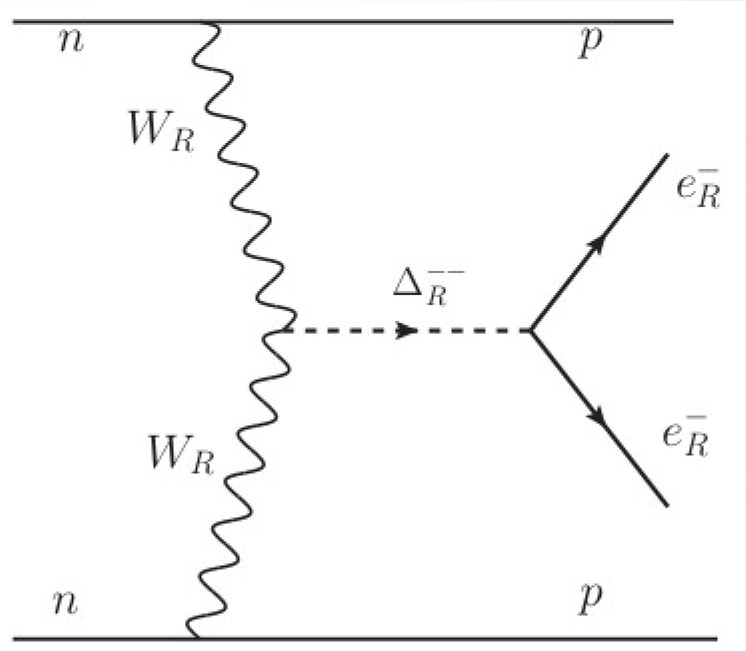

$$\mathrm{A}^{LL}_{\Delta_L} \propto G_F^2 \sum_i^3 \frac{(U_L)^2_{ei} m_i}{M^2_{\Delta_L}}$$

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- From limits in $T_{1/2}$ can find limits in m^{ee}_{υ} and m^{ee}_{N}

Limits

- For standard mechanism

Isotope	Half-life $T_{1/2}^{0\nu\beta\beta}$ (Yrs)	m_ν^{ee} (eV)	$\frac{1}{m_N^{ee}}$ (GeV^{-1})
^{76}Ge	3.0×10^{25}	$0.29 - 0.74$	$(0.97 - 1.72) \times 10^{-8}$
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- Limits assume contribution for only one mechanism at a time

Limits LRSM

- For LRSM

$$\eta_\nu^{RR} = \frac{M_{W_L}^4}{M_{W_R}^4} \sum_i^3 \frac{(S^*)_{ei}^2 m_i}{m_e}\,, \qquad \eta_N^{RR} = \frac{M_{W_L}^4}{M_{W_R}^4} \sum_i^3 \frac{(U_R^*)_{ei}^2 m_p}{M_i}$$

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$$\eta_{\Delta_L}^{LL} = \sum_i^3 \frac{(U_L)_{ei}^2 m_i m_e}{M_{\Delta_L}^2}\,, \qquad \eta_{\Delta_R}^{RR} = \frac{M_{W_L}^4}{M_{W_R}^4} \sum_i^3 \frac{(U_R^*)_{ei}^2 M_i m_p}{M_{\Delta_R}^2}$$

Limits LRSM

Mechanism	New physics parameters	^{76}Ge Limit	^{136}Xe Limit
$\mathcal{A}_{\nu}^{RR}$	$\sum_i^3 \frac{(S^*)^2_{ei} m_i}{M^4_{W_R}}$	$(0.70 - 1.77) \times 10^{-17}\, GeV^{-3}$	$(0.60 - 1.49) \times 10^{-17}\, GeV^{-3}$
$\mathcal{A}_{N}^{RR}$	$\sum_i^3 \frac{(U^*_R)^2_{ei}}{M^4_{W_R} M_i}$	$(2.32 - 4.12) \times 10^{-16}\, GeV^{-5}$	$(2.83 - 2.97) \times 10^{-16}\, GeV^{-5}$
$\mathcal{A}_{\nu}^{LR}$	$\sum_i^3 \frac{(U_L)_{ei}(S^*)_{ei}}{M^2_{W_R}}$	$(1.54 - 3.32) \times 10^{-10}\, GeV^{-2}$	$(1.18 - 1.50) \times 10^{-10}\, GeV^{-2}$
$\mathcal{A}_{N}^{LR}$	$\sum_i^3 \frac{(T)_{ei}(U^*_R)_{ei}}{M^2_{W_R} M^2_i}$	$(1.95 - 2.04) \times 10^{-12}\, GeV^{-4}$	$(1.60 - 2.83) \times 10^{-12}\, GeV^{-4}$
$\mathcal{A}_{\Delta_L}^{LL}$	$\sum_i^3 \frac{(U_L)^2_{ei} m_i}{M^2_{\Delta_L}}$	$\sim 10^{-8}\, GeV^{-1}$	$\sim 10^{-8}\, GeV^{-1}$
$\mathcal{A}_{\Delta_R}^{RR}$	$\sum_i^3 \frac{(U^*_R)^2_{ei} M_i}{M^2_{\Delta_R} M^4_{W_R}}$	$\sim (10^{-16} - 10^{-15})\, GeV^{-5}$	$\sim (10^{-16} - 10^{-15})\, GeV^{-5}$

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- Some mechanisms are highly suppressed and it is important to consider relative magnitude of the different mechanisms
- Interference and cancellation between different mechanisms might occur
- There are many other possible contributions to $0\nu\beta\beta$. Real challenge is to identify the underlying mechanism that drives the decay

Going Forward

- Katrin → Half live of 6 x 10^{27} Years

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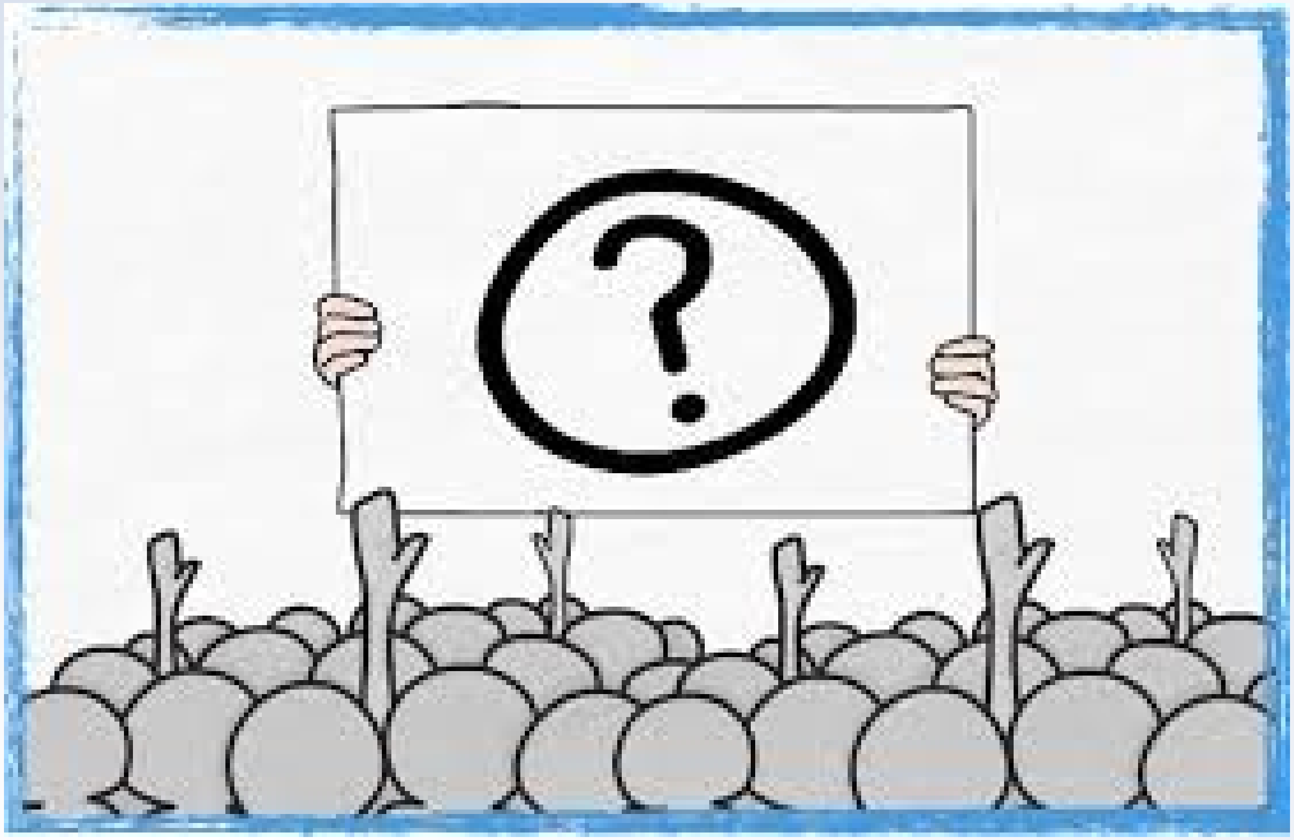
- Can shine some light into BSM physics models and set bounds in new physics parameters
- The LRSM is an attractive extension of the SM which could be falsified at the LHC and has a clear signature in $0\nu\beta\beta$ experiments

Questions



- Questions??