Doubly charged Higgs scalars and spontaneous symmetry breaking at eV and TeV energy scales

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AIM OF STUDIES

Discovery of the Higgs particle at the LHC in 2012 confirmed the mechanism of mass generation predicted by the Standard Model. However the Standard Model leaves some problems unsolved and many attempts to construct more sophisticated theory are undertaken. This poster will concentrate on models with triplet scalar extension, without modification of the gauge group (Higgs Triplet Model - HTM), and with an extended gauge group $SU(2)_R \times SU(2)_L \times U(1)_Y$ (Left Right Symmetry Model - LRSM). Those two models differ in the triplet vacuum expectation values (VEVs). The $SU(2)_L$ triplet VEV is limited by the ρ parameter from the above at the range of GeV. In the case of the LRSM the $SU(2)_R$ triplet VEV reach at least the range of TeV to provide heavy non-standard particles' masses. Additional triplets in the scalar sector involve existence of new scalar particles, singly and doubly charged, depends on the hypercharge of the implemented triplet. Both types of particles can contribute to (g-2)μ and LFV processes. Keeping in mind those low energy constrains it is possible to limit the parameters space and analyze signals which could be observed at the CLIC collider.

EXTENSIONS OF THE SCALAR SECTOR

$$\Delta = \begin{pmatrix} \frac{\Delta^+}{\sqrt{2}} & \Delta^{++} \\ \Delta^0 & \frac{\Delta^+}{\sqrt{2}} \end{pmatrix}$$

Following the convention Q = Y + T_3, and addional triplet with the Y=1 hypercharge contains singly and doubly charged scalar fields. $SU(2)_L$ multiplets other than doublets modify value of the ρ parameter [1].
v_Δ < 1 GeV

$$\rho = \frac{1+2\frac{v_\Delta^2}{v_\phi^2}}{1+4\frac{v_\Delta^2}{v_\phi^2}}$$

Experimental value [2]:

ρ^{exp} = 1.00037 ± 0.00023

HIGGS TRIPLET MODEL (HTM)

Based on the Standard Model gauge group.
One additional scalar triplet with the hypercharge Y = 1.
Neutrino masses are introduced due to the type II see-saw mechanism.
New scalar fields: H^0, A^0, $H^\pm$,$H^{\pm\pm}$
Small, but non-zero vaccum expectation value of the scalar triplet v_Δ

Vertex $H^{\pm\pm}$ - l_i - l_j : $$\frac{1}{\sqrt{2}v_\Delta} V^*_{PMNS} D_\nu V_{PMNS}$$

LEFT RIGHT SYMMETRIC MODEL (LRSM)

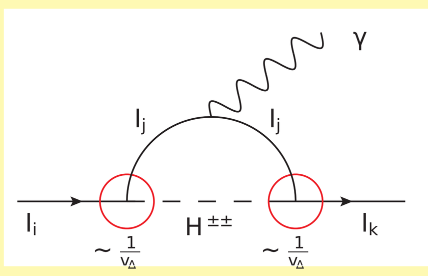
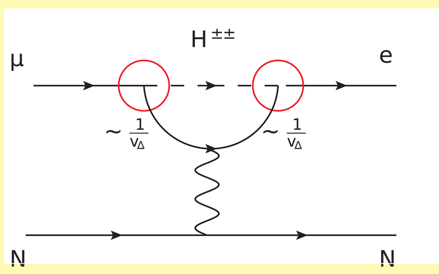
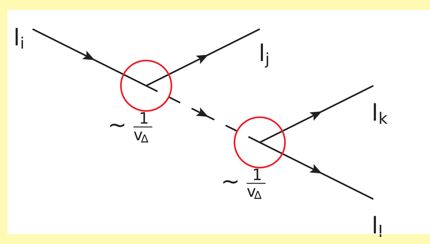
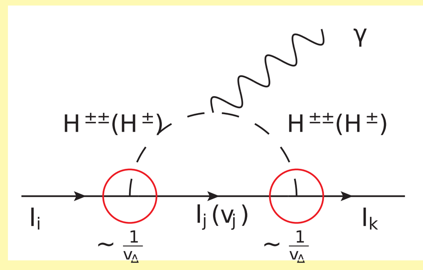
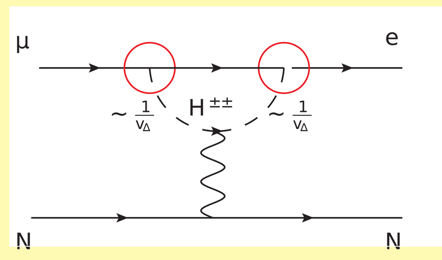
Based on the extended gauge group $SU(2)_L$ x $SU(2)_R$ x U(1).
Two additional scalar fields triplets under the $SU(2)_L$ i $SU(2)_R$ groups.
Additional heavy neutrino states N_1, N_2, N_3 - see-saw type I.
New scalar fields: H_1^0, H_2^0, H_3^0, A_1^0, A_2^0, $H_1^\pm$, $H_2^\pm$, $H_1^{\pm\pm}$, $H_2^{\pm\pm}$.
Heavy gauge bosons: $W_2^\pm$, Z_2.
$SU(2)_L$ triplet VEV v_L = 0, for the $SU(2)_R$ triplet: v_R ~ TeV.

Vertex $H^{\pm\pm}$ - l_i - l_i : $$\frac{2i}{\sqrt{2}v_R} M_{N_i}$$

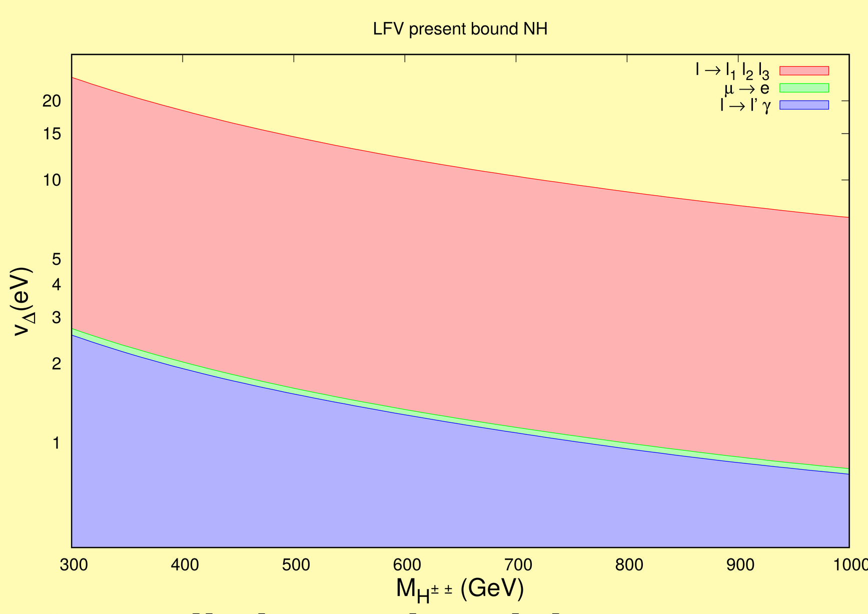
LOW ENERGY CONSTRAINTS - LEPTON NUMBER / FLAVOUR VIOLATING PROCESSES

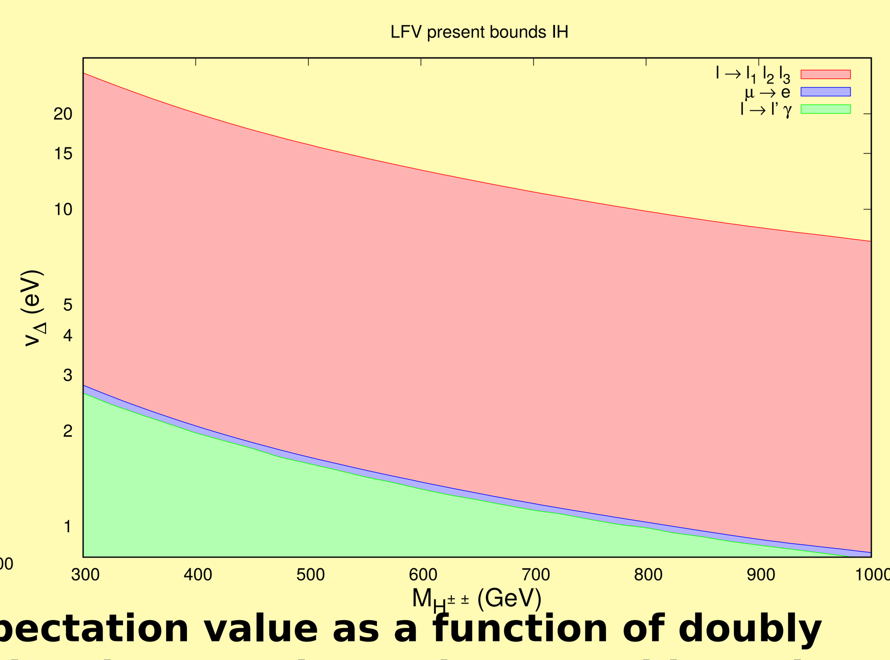
Eksperimental limits on the LNV and LFV processes [3-6] and corresponding Feynman diagrams with doubly charged scalar's mediation.

Process:	Limits:
BR $(\mu \to e\gamma)$	5.7×10^{-13}
BR $(\tau \to e\gamma)$	3.3×10^{-8}
BR $(\tau \to \mu\gamma)$	4.4×10^{-8}
BR $(\tau \to 3\mu)$	2.1×10^{-8}
BR $(\tau \to e\mu\mu)$	2.7×10^{-8}
BR $(\mu N \to eN^*)$ (for Au)	7.0×10^{-13}

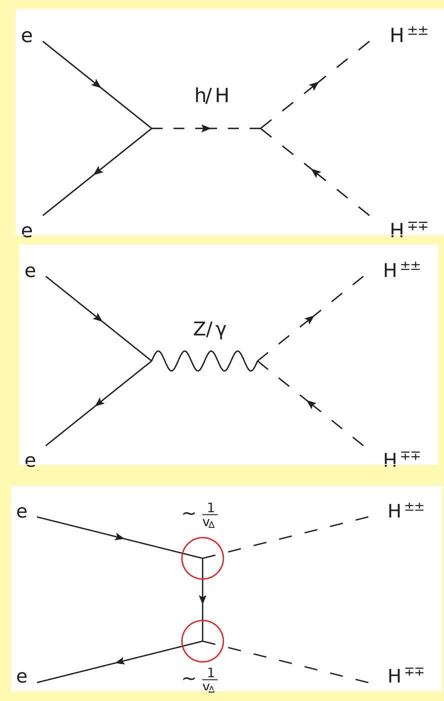
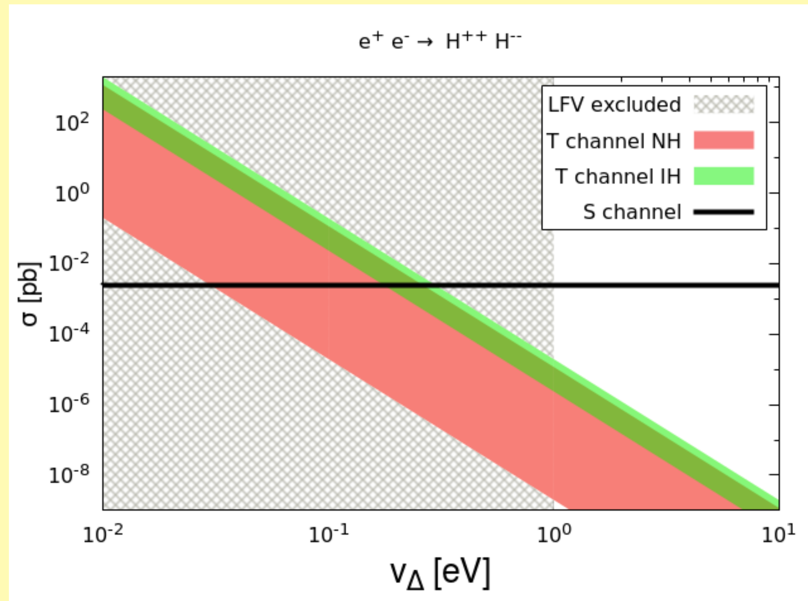
v_Δ vs $M_{H\pm\pm}$ (HTM):





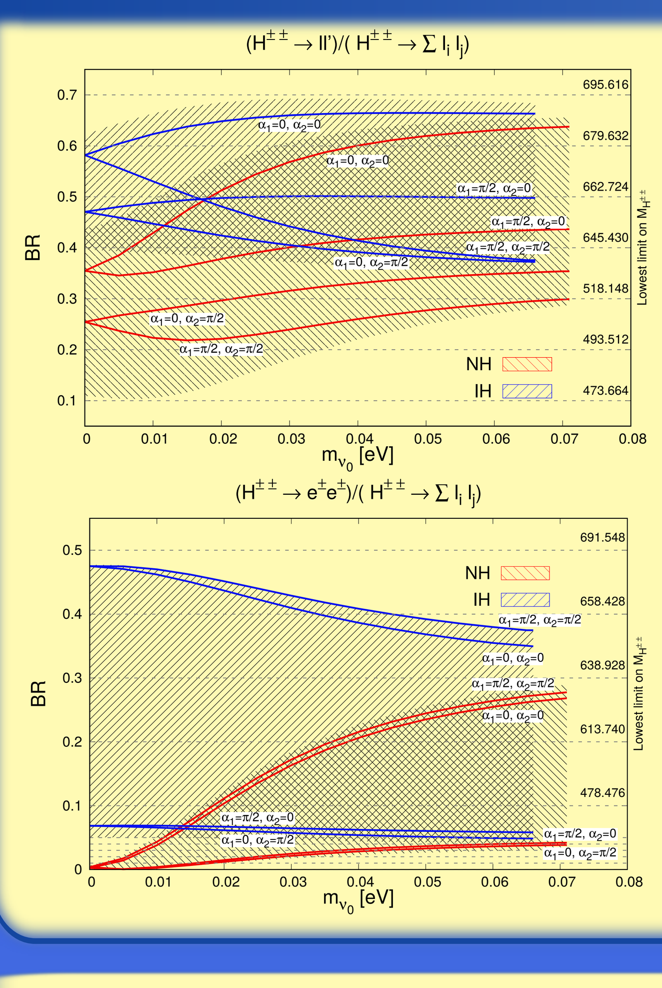
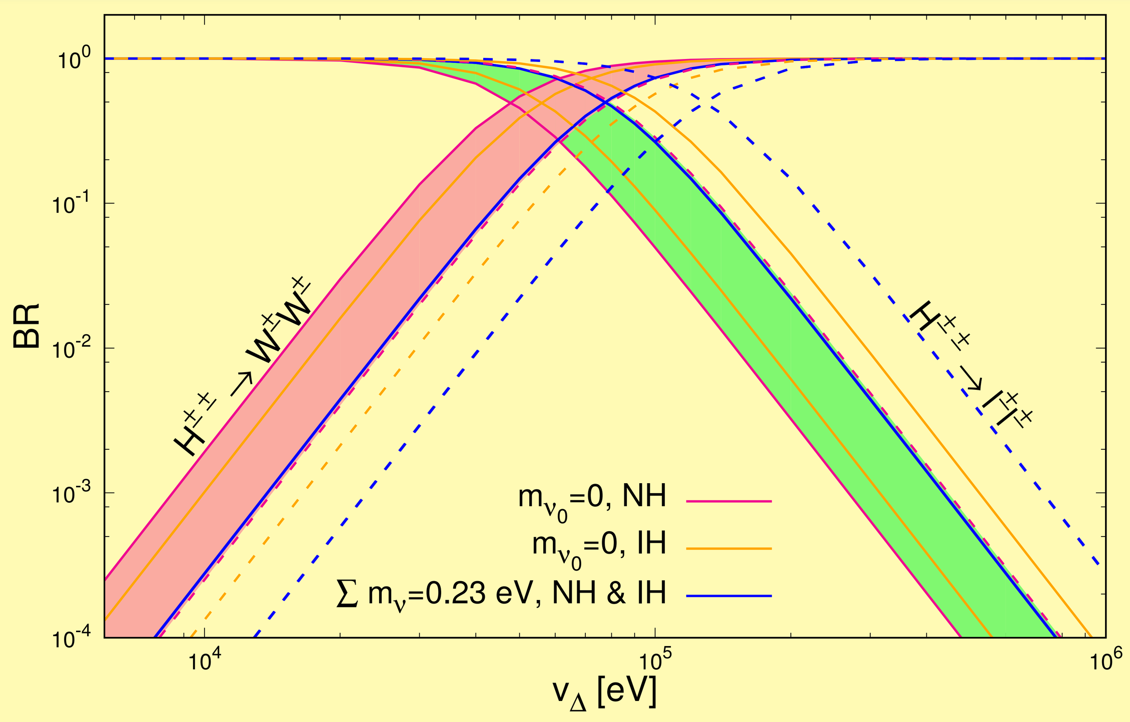
Lower limits on the triplet vaccum expectation value as a function of doubly charged scalar particle's mass. Normal and Inverted neutrino mass hierarchy.

$H^{\pm\pm}$ IN e^+e^- COLLIDER

Doubly charged scalar particles pair production in e^+e^- collision at energy 1.5 TeV within the HTM.

$H^{\pm\pm}$ DECAYS:

Doubly charged scalar particle's decay channels within the HTM. Decays to $H^\pm$ are suppressed.

HTM AND LRSM - COMPARISON

signal	SM	HTM		LRSM
		NH	IH	
$eeee$	235.0	28.2	87.1	130.5
$\mu\mu\mu\mu$	65.9	160.9	106.9	197.4

4l sygnal comming from $H^{\pm\pm}$ pair production in e^+e^- collision at enegy 1.5 TeV for HTM i LRSM. Luminosity L=1500 fb^{-1}. $H^{\pm\pm}$ mass $M_{H\pm\pm}$ = 700 GeV.

REFERENCES:

[1] T. G. Rizzo, Phys.Rev.D 21,1404 (1980)
[2] M. Aoki, S. Kanemura, Phys.Rev.D 77,095009 (2008)
[3] J. Adam et al. (MEG), Phys.Rev.Lett. 110,201801 (2013)
[4] B. Aubert et al. (BaBar), Phys.Rev.Lett. 104,021802(2010)
[5] K. Hayasaka et al., Phys.Lett. B687,139 (2010)
[6] W. H. Bertl et al. (SINDRUM II), Eur. Phys. J. C47,337 (2006).

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