Probing Type-II Seesaw Mechanism in Alternative $U(1)_X$ Model

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Introduction and Motivation:-

- One of the problems of Standard Model: Origin of ν mass
- One simple solution: Type-II seesaw mechanism
- Investigation of doubly charged scalar production in Type-II seesaw at LHC.
- Probe Type-II seesaw with $\Delta^{\pm\pm}$ pair production, followed by it's decay to the same sign dilepton ($\Delta^{\pm\pm} \rightarrow l^{\pm}l^{\pm}$)

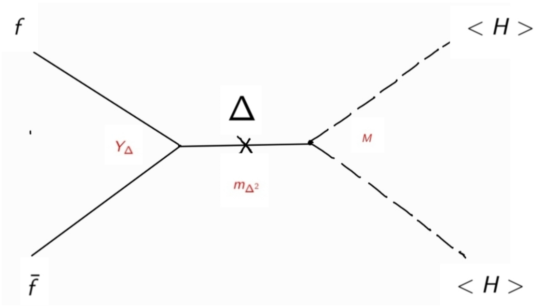
Type II Seesaw Mechanism

- Originally proposed by : –
  Lazarides, Shafi, Wetterich, NPB 181 (1981), 287-300;
  Mahapatra, Senjanović, PRD 23 (1981), 161.

Particle	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$
q_L	3	2	$\frac{1}{6}$
u_R	3	1	$\frac{2}{3}$
d_R	3	1	$-\frac{1}{3}$
l_L	1	2	$-\frac{1}{2}$
e_R	1	1	-1
H	1	2	$\frac{1}{2}$
Δ	1	3	1

Type II Seesaw Mechanism continued

- Massive BSM Triplet scalar Δ mixing considered to explain SM ν's small mass, where
$$\Delta = \begin{bmatrix} \frac{1}{\sqrt{2}}\Delta_+ & \Delta_{++} \\ \Delta_0 & -\frac{1}{\sqrt{2}}\Delta_+ \end{bmatrix}$$
- Symmetry breaking generates Majorana mass $\frac{Y_\Delta M v^2}{m_\Delta^2}$



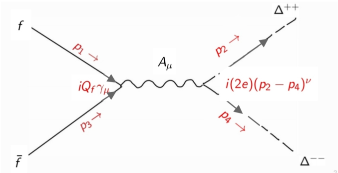
$U(1)_X$ extended SM with Type-II Seesaw Mechanism:-

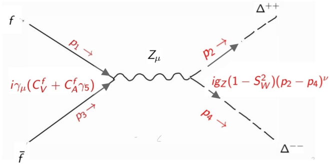
- Symmetry imposed is $SU(3)_C \times SU(2)_L \times U(1)_Y \times U(1)_X$ for this model. Ref:-Okada, Seto, PRD105 (2022) 12
- 3 BSM ν_R, 2 doublet Higgs, 1 triplet Higgs and 1 scalar considered in this model.

	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$U(1)_X$	
q_L^i	3	2	$\frac{1}{6}$	$\frac{1}{6}x_H + \frac{1}{3}$	
u_R^i	3	1	$\frac{2}{3}$	$\frac{2}{3}x_H + \frac{1}{3}$	
d_R^i	3	1	$\frac{-1}{3}$	$-\frac{1}{3}x_H + \frac{1}{3}$	
l_L^i	1	2	$\frac{-1}{2}$	$-\frac{1}{2}x_H - 1$	
e_R^i	1	1	-1	$-x_H - 1$	
ν_R^1	1	1	-1	-4	Alternate
${\nu_R}^2$	1	1	-1	-4	Charge
${\nu_R}^3$	1	1	-1	5	Assigned-DM
Φ_1	1	2	$\frac{1}{2}$	$\frac{1}{2}x_H + 1$	
Φ_2	1	2	$\frac{1}{2}$	$\frac{1}{2}x_H$	
Δ_3	1	3	1	$x_H + 2$	Type-II Seesaw scalar
Φ_X	1	1	0	1	For $U(1)_X$ breaking

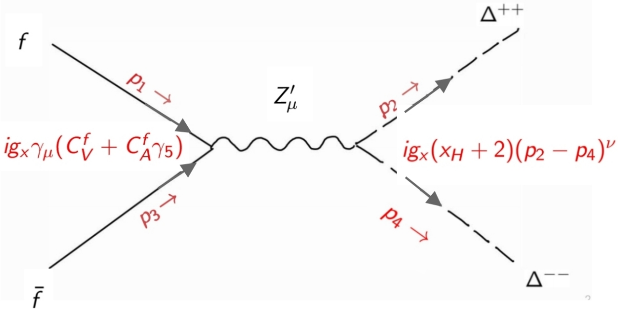
Δ pair production at LHC:-

1. SM gauge boson mediated:-



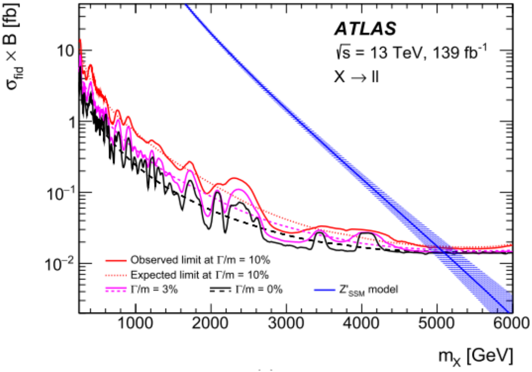


2. New Process Z' mediated:-



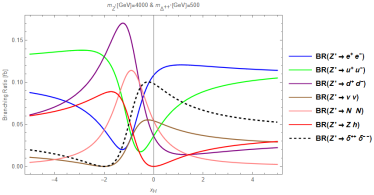
Constraint on Z' boson production from LHC Run-2:-

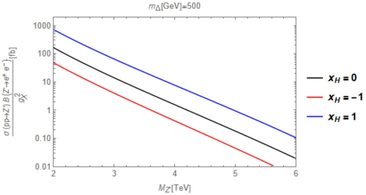
- ATLAS and LHC searching for narrow resonance (Z' boson) with dileptons as final states ($e^{\pm}$,$\mu^{\pm}$)
- The upper bound on $\sigma(pp \to Z')B(Z' \to e^{\pm}, \mu^{\pm})$ obtained



Constraint on Z' boson production from LHC Run-2 Cont'd:-

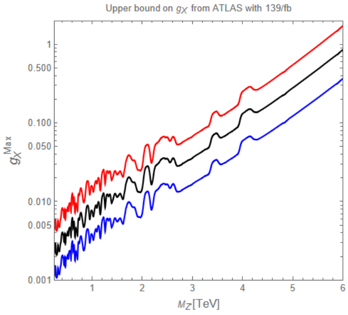
- Z' boson branching ratio depends on x_H
- We calculate $\sigma(pp \to Z')B(Z' \to e^{\pm}, \mu^{\pm})$ for various x_H





Constraint on Z' boson production from LHC Run-2 Cont'd:-

- We interpret the ATLAS bound to calculate the upper bound of g_X



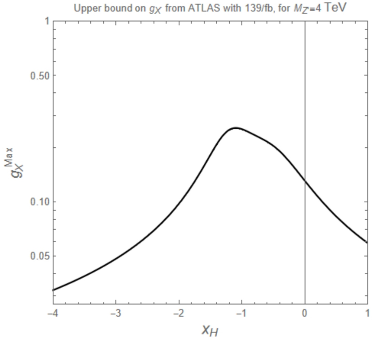
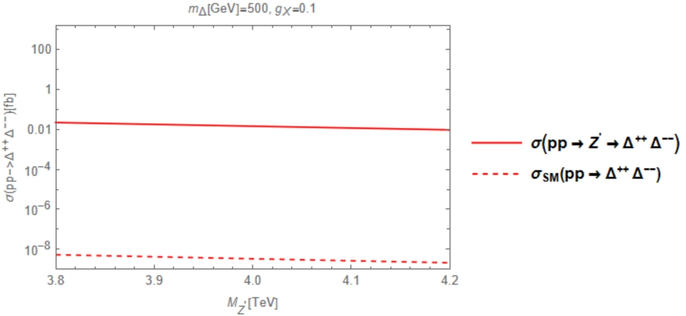


Figure: (a) g_X vs. $M_{Z'}$, (b) g_X vs. x_H

Doubly Charged $\Delta^{\pm\pm}$ production at LHC: Comparison between BSM and SM processes:-

- We set $g_x = .1$ and $x_H = 0$ for $M_{Z'}[TeV] = 4$ from LHC constraints.
- Cross section calculated for invariant mass in range of $.95M_{Z'} \leq E \leq 1.05M_{Z'}$ resulting in $\sigma_{(pp\to Z'\to\Delta^{++}\Delta^{--})} \gg \sigma_{SM(pp\to\Delta^{++}\Delta^{--})}$



Summary:

1. $U(1)_X$ extended framework proposed to accommodate Type-II Seesaw scalar at LHC.
2. We have considered $\Delta^{\pm\pm}$ production from Z' decay .
3. Focusing on $\Delta^{\pm\pm}$ pair production around $M_{Z'}$ for the invariant mass, Z' mediated process dominates over SM gauge boson mediated processes.

Future Plan:- Simulation study focusing on the invariant

mass range of $m_{Z'}$ - δE $\leq$ E $\leq$ $m_{Z'} + \delta$E, to optimize the chance of detecting $\Delta^{\pm\pm}$, while reducing the SM background.