

The Left-Right Symmetric Model Charged Sector

 W_R Mass Limit at the LHC

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Results

Scenario I: $\begin{array}{l} M_{\mathcal{V}_R} > M_{W_R} \\ \text{Scenario II:} \\ M_{\mathcal{V}_R} < M_{W_R} \\ \text{Correlating } W_R \text{ and } \nu_R \\ \text{mass bounds} \end{array}$

Conclusion

Relaxing LHC constraints on the W_R mass

based on Phys. Rev. D 99, 035001

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Motivatio

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Scenario I: $M_{\nu_R} > M_{W_R}$ Scenario II: $M_{\nu_R} < M_{W_R}$

Correlating W_{R} and $\mathit{\nu}_{\mathit{R}}$ mass bounds



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at the LHC

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 $\begin{array}{l} {\rm M}_{\mathcal{V}_R} > {\rm M}_{W_R} \\ {\rm Scenario \ II:} \\ {\rm M}_{\mathcal{V}_R} < {\rm M}_{W_R} \\ {\rm Correlating \ } W_R \ {\rm and \ } \nu_R \\ {\rm mass \ bounds} \end{array}$

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The Left-Right Symmetric Model (LRSM)

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The Left-Right Symmetric Model

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	Fields	$SU(2)_L \times SU(2)_R \times U(1)_{B-L}$
r	Q_{L_i}	$(2,1,+\frac{1}{3})$
Matter	Q_{R_i}	$(1,2,-\frac{1}{3})$
	L_{L_i}	(2 , 1 ,-1)
	L_{R_i}	(1, 2, -1)
S	Ф	(2, 2, 0)
Higgs	Δ_L	(3, 1, 2)
	Δ_R	(1, 3, 2)

$$Q_{Li} = \begin{pmatrix} u_L \\ d_L \end{pmatrix}_i \sim (\mathbf{2}, \mathbf{1}, \mathbf{1}/\mathbf{3}), \quad Q_{Ri} = \begin{pmatrix} u_R \\ d_R \end{pmatrix}_i \sim (\mathbf{1}, \mathbf{2}, \mathbf{1}/\mathbf{3}),$$

$$L_{Li} = \begin{pmatrix}
u_L \\ \ell_L \end{pmatrix}_i \sim (\mathbf{2}, \mathbf{1}, -\mathbf{1}) \,, \ \ L_{Ri} = \begin{pmatrix}
u_R \\ \ell_R \end{pmatrix}_i \sim (\mathbf{1}, \mathbf{2}, -\mathbf{1}) \,,$$

$$SU(3)_C \times SU(2)_L \times \frac{SU(2)_R \times U(1)_{B-L}}{\bigvee_{\Phi}} \Delta_R$$

$$SU(3)_C \times SU(2)_L \times \frac{U(1)_Y}{\bigvee_{\Phi}}$$

$$SU(3)_C \times U(1)_{EM}$$

$$\Phi \equiv egin{pmatrix} \phi_1^0 & \phi_2^+ \ \phi_1^- & \phi_2^0 \end{pmatrix} \sim (\mathbf{2},\mathbf{2},\mathbf{0})$$

$$\Delta_L \equiv egin{pmatrix} \delta_L^+/\sqrt{2} & \delta_L^{++} \ \delta_L^0 & -\delta_L^+/\sqrt{2} \end{pmatrix} \sim (\mathbf{3},\mathbf{1},\mathbf{2})$$

$$\Delta_R \equiv \begin{pmatrix} \delta_R^+/\sqrt{2} & \delta_R^{++} \\ \delta_R^0 & -\delta_R^+/\sqrt{2} \end{pmatrix} \sim (\mathbf{1},\mathbf{3},\mathbf{2})$$



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Conclusion

Symmetry Breaking

$$SU(2)_R \otimes U(1)_{B-L} \longrightarrow U(1)_Y$$

$$\langle \Delta_L \rangle = \begin{pmatrix} 0 & 0 \\ v_L e^{i\theta_L}/\sqrt{2} & 0 \end{pmatrix}, \quad \langle \Delta_R \rangle = \begin{pmatrix} 0 & 0 \\ v_R/\sqrt{2} & 0 \end{pmatrix}$$



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$$SU(2)_L \otimes U(1)_Y \longrightarrow U(1)_{EM}$$
 $v_R \gg (\kappa_1, \ \kappa_2) \gg v_L, \qquad \sqrt{\kappa_1^2 + \kappa_2^2} = v = 246 \; {\sf GeV}$ $\langle \Phi \rangle = egin{pmatrix} \kappa_1/\sqrt{2} & 0 \ 0 & \kappa_2 e^{i lpha}/\sqrt{2} \end{pmatrix}$



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Scenario I: $\begin{aligned} &M_{\mathcal{V}_R} > M_{W_R} \\ &S &\in \mathbf{M}_{W_R} \end{aligned}$ Scenario II: $&M_{\mathcal{V}_R} < M_{W_R} \\ &C &orrelating W_R \text{ and } \nu_R \\ &\text{mass bounds} \end{aligned}$

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LRSM Lagrangian

$$\mathcal{L}_{\mathrm{LRSM}} = \mathcal{L}_{\mathrm{kin}} + \mathcal{L}_{Y} - V(\Phi, \Delta_{L}, \Delta_{R})$$



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LRSM Lagrangian

$$\mathcal{L}_{\mathrm{LRSM}} = \mathcal{L}_{\mathrm{kin}} + \mathcal{L}_{Y} - V(\Phi, \Delta_{L}, \Delta_{R})$$

$$\mathcal{L}_{
m kin}=i\sumar{\psi}\gamma^{\mu}D_{\mu}\psi$$

$$\begin{split} &= \bar{L}_L \gamma^{\mu} \left(i \partial_{\mu} + g_L \frac{\vec{\tau}}{2} \cdot \vec{W}_{L\mu} - \frac{g_{B-L}}{2} B_{\mu} \right) L_L + \bar{L}_R \gamma^{\mu} \left(i \partial_{\mu} + g_R \frac{\vec{\tau}}{2} \cdot \vec{W}_{R\mu} - \frac{g_{B-L}}{2} B_{\mu} \right) L_R \\ &+ \bar{Q}_L \gamma^{\mu} \left(i \partial_{\mu} + g_L \frac{\vec{\tau}}{2} \cdot \vec{W}_{L\mu} + \frac{g_{B-L}}{6} B_{\mu} \right) Q_L + \bar{Q}_R \gamma^{\mu} \left(i \partial_{\mu} + g_R \frac{\vec{\tau}}{2} \cdot \vec{W}_{R\mu} + \frac{g_{B-L}}{6} B_{\mu} \right) Q_R \end{split}$$



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LRSM Lagrangian

$$\mathcal{L}_{\mathrm{LRSM}} = \mathcal{L}_{\mathrm{kin}} + \mathcal{L}_{Y} - V(\Phi, \Delta_{L}, \Delta_{R})$$

$$\mathcal{L}_{\rm kin} = i \sum \bar{\psi} \gamma^{\mu} D_{\mu} \psi$$

$$\begin{split} &= \bar{L}_L \gamma^\mu \left(i \partial_\mu + g_L \frac{\vec{\tau}}{2} \cdot \vec{W}_{L\mu} - \frac{g_{B-L}}{2} B_\mu \right) L_L + \bar{L}_R \gamma^\mu \left(i \partial_\mu + g_R \frac{\vec{\tau}}{2} \cdot \vec{W}_{R\mu} - \frac{g_{B-L}}{2} B_\mu \right) L_R \\ &+ \bar{Q}_L \gamma^\mu \left(i \partial_\mu + g_L \frac{\vec{\tau}}{2} \cdot \vec{W}_{L\mu} + \frac{g_{B-L}}{6} B_\mu \right) Q_L + \bar{Q}_R \gamma^\mu \left(i \partial_\mu + g_R \frac{\vec{\tau}}{2} \cdot \vec{W}_{R\mu} + \frac{g_{B-L}}{6} B_\mu \right) Q_R \end{split}$$

$$\mathcal{L}_{Y} = -\left[Y_{L_{L}}\bar{L}_{L}\Phi L_{R} + \tilde{Y}_{L_{R}}\bar{L}_{R}\Phi L_{L} + Y_{Q_{L}}\bar{Q}_{L}\tilde{\Phi}Q_{R} + \tilde{Y}_{Q_{R}}\bar{Q}_{R}\tilde{\Phi}Q_{L} + \mathbf{h}_{I}^{ij}\bar{L}_{L_{i}}^{c}i\tau_{2}\Delta_{L}L_{L_{i}} + \mathbf{h}_{R}^{ij}\bar{L}_{R_{i}}^{c}i\tau_{2}\Delta_{R}L_{R_{i}} + \text{h.c.}\right],$$



The Left-Right Symmetric Model

 $M_{\nu_{-}} > M_{\nu_{-}}$ $M_{\nu} < M_{W}$

LRSM Higgs Potential

$$\begin{split} V(\phi,\Delta_L,\Delta_R) &= -\mu_1^2 \left(\mathrm{Tr} \left[\Phi^\dagger \Phi \right] \right) - \mu_2^2 \left(\mathrm{Tr} \left[\tilde{\Phi} \Phi^\dagger \right] + \left(\mathrm{Tr} \left[\tilde{\Phi}^\dagger \Phi \right] \right) \right) - \mu_3^2 \left(\mathrm{Tr} \left[\Delta_L \Delta_L^\dagger \right] + \mathrm{Tr} \left[\Delta_R \Delta_R^\dagger \right] \right) \\ &+ \lambda_1 \left(\left(\mathrm{Tr} \left[\Phi \Phi^\dagger \right] \right)^2 \right) + \lambda_2 \left(\left(\mathrm{Tr} \left[\tilde{\Phi} \Phi^\dagger \right] \right)^2 + \left(\mathrm{Tr} \left[\tilde{\Phi}^\dagger \Phi \right] \right)^2 \right) + \lambda_3 \left(\mathrm{Tr} \left[\tilde{\Phi} \Phi^\dagger \right] \mathrm{Tr} \left[\tilde{\Phi}^\dagger \Phi \right] \right) \right) \\ &+ \lambda_4 \left(\mathrm{Tr} \left[\Phi \Phi^\dagger \right] \left(\mathrm{Tr} \left[\tilde{\Phi} \Phi^\dagger \right] + \mathrm{Tr} \left[\tilde{\Phi}^\dagger \Phi \right] \right) \right) + \rho_1 \left(\left(\mathrm{Tr} \left[\Delta_L \Delta_L^\dagger \right] \right)^2 + \left(\mathrm{Tr} \left[\Delta_R \Delta_R^\dagger \right] \right)^2 \right) \\ &+ \rho_2 \left(\mathrm{Tr} \left[\Delta_L \Delta_L \right] \mathrm{Tr} \left[\Delta_L^\dagger \Delta_L^\dagger \right] + \mathrm{Tr} \left[\Delta_R \Delta_R \right] \mathrm{Tr} \left[\Delta_R^\dagger \Delta_R^\dagger \right] \right) + \rho_3 \left(\mathrm{Tr} \left[\Delta_L \Delta_L^\dagger \right] \mathrm{Tr} \left[\Delta_R \Delta_R^\dagger \right] \right) \\ &+ \rho_4 \left(\mathrm{Tr} \left[\Delta_L \Delta_L \right] \mathrm{Tr} \left[\Delta_R^\dagger \Delta_R^\dagger \right] + \mathrm{Tr} \left[\Delta_L^\dagger \Delta_L^\dagger \right] \mathrm{Tr} \left[\Delta_R \Delta_R \right] \right) + \alpha_1 \mathrm{Tr} \left[\Phi \Phi^\dagger \right] \left(\mathrm{Tr} \left[\Delta_L \Delta_L^\dagger \right] + \mathrm{Tr} \left[\Delta_R \Delta_R^\dagger \right] \right) \\ &+ \alpha_2 \left(\mathrm{Tr} \left[\Phi \tilde{\Phi}^\dagger \right] \mathrm{Tr} \left[\Delta_R \Delta_R^\dagger \right] + \mathrm{Tr} \left[\Phi^\dagger \tilde{\Phi} \right] \mathrm{Tr} \left[\Delta_L \Delta_L^\dagger \right] \right) + \alpha_2^* \left(\mathrm{Tr} \left[\Phi^\dagger \tilde{\Phi} \right] \mathrm{Tr} \left[\Delta_R \Delta_R^\dagger \right] + \mathrm{Tr} \left[\tilde{\Phi}^\dagger \Phi \Delta_L \Delta_L^\dagger \right] \right) \\ &+ \alpha_3 \left(\mathrm{Tr} \left[\Phi \Phi^\dagger \Delta_L \Delta_L^\dagger \right] + \mathrm{Tr} \left[\Phi^\dagger \Phi \Delta_R \Delta_R^\dagger \right] \right) + \beta_1 \left(\mathrm{Tr} \left[\Phi \Delta_R \Phi^\dagger \Delta_L^\dagger \right] + \mathrm{Tr} \left[\Phi^\dagger \Delta_L \Phi \Delta_R^\dagger \right] \right) \\ &+ \beta_2 \left(\mathrm{Tr} \left[\tilde{\Phi} \Delta_R \Phi^\dagger \Delta_L^\dagger \right] + \mathrm{Tr} \left[\tilde{\Phi}^\dagger \Delta_L \Phi \Delta_R^\dagger \right] \right) + \beta_3 \left(\mathrm{Tr} \left[\Phi \Delta_R \tilde{\Phi}^\dagger \Delta_L^\dagger \right] + \mathrm{Tr} \left[\Phi^\dagger \Delta_L \tilde{\Phi} \Delta_R^\dagger \right] \right) \end{split}$$



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Scenario I: $\begin{aligned} &M_{\mathcal{V}_R} > M_{W_R} \\ &\text{Scenario II:} \\ &M_{\mathcal{V}_R} \leqslant M_{W_R} \\ &\text{Correlating } W_R \text{ and } \nu_R \end{aligned}$

Conclusion

Gauge Sector

$$\begin{pmatrix} Z_R^{\mu} \\ B^{\mu} \end{pmatrix} = \begin{pmatrix} \cos \phi & -\sin \phi \\ \sin \phi & \cos \phi \end{pmatrix} \begin{pmatrix} W_R^{3\mu} \\ V^{\mu} \end{pmatrix}$$



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$$\left(\begin{array}{c} Z_R^\mu \\ B^\mu \end{array} \right) = \left(\begin{array}{cc} \cos\phi & -\sin\phi \\ \sin\phi & \cos\phi \end{array} \right) \left(\begin{array}{c} W_R^{3\mu} \\ V^\mu \end{array} \right)$$

$$\begin{pmatrix} Z_L^\mu \\ B^\mu \\ Z_R^\mu \end{pmatrix} = \begin{pmatrix} \cos\theta_W & -\sin\theta_W \sin\phi & -\sin\theta_W \cos\phi \\ \sin\theta_W & \cos\theta_W \sin\phi & \cos\theta_W \cos\phi \\ 0 & \cos\phi & -\sin\phi \end{pmatrix} \begin{pmatrix} W_L^{3\mu} \\ W_R^{3\mu} \\ V^\mu \end{pmatrix}$$

$$M_A=0$$

$$\begin{split} M_{Z_{1,2}}^2 &= \frac{1}{4} \Big[\left[g_L^2 v^2 + 2 v_R^2 (g_R^2 + g_{B-L}^2) \right] \\ &\mp \sqrt{ \left[g_L^2 v^2 + 2 v_R^2 (g_R^2 + g_{B-L}^2) \right]^2 - 4 g_L^2 (g_R^2 + 2 g_{B-L}^2) v^2 v_R^2} \Big] \,. \end{split}$$



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$$\left(\begin{array}{c} W_1 \\ W_2 \end{array}\right) = \left(\begin{array}{cc} \cos \xi & -\sin \xi \\ \sin \xi & \cos \xi \end{array}\right) \left(\begin{array}{c} W_L \\ W_R \end{array}\right)$$



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$$\left(\begin{array}{c} W_1 \\ W_2 \end{array}\right) = \left(\begin{array}{cc} \cos \xi & -\sin \xi \\ \sin \xi & \cos \xi \end{array}\right) \left(\begin{array}{c} W_L \\ W_R \end{array}\right)$$

In the limit of $(\kappa_1, \kappa_2) \ll v_R$ and $g_R \sim g_L$ we have $\sin \xi \approx \frac{\kappa_1 \kappa_2}{v_R^2}$, $\sin^2 \xi \approx 0$, $\cos \xi \approx 1$, leading to

$$M_{W_1}^2 = \frac{1}{4}g_L^2v^2, \qquad M_{W_2}^2 = \frac{1}{4}\left[2g_R^2v_R^2 + g_R^2v^2 + 2g_Rg_L\frac{\kappa_1^2\kappa_2^2}{v_R^2}\right]$$



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Correlating W_R and ν_R mass bounds



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$\ensuremath{\mathsf{W}_R}$ Mass Limits at the LHC

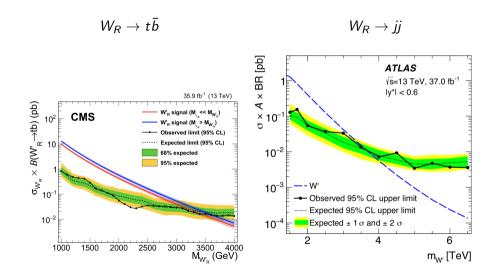
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W_R Mass Limits at the LHC





W_R Mass Limits at the LHC

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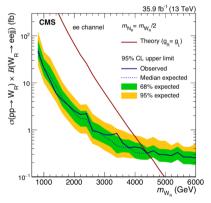
$\ensuremath{\mathsf{W}_R}$ Mass Limits at the LHC

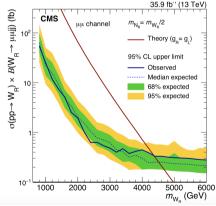
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Scenario I: $\begin{array}{l} M_{\mathcal{V}_R} > M_{W_R} \\ \text{Scenario II:} \\ M_{\mathcal{V}_R} < M_{W_R} \\ \text{Correlating } W_R \text{ and } \nu_{\text{mass bounds}} \end{array}$

$$W_R \to \ell \nu_R \to \ell \ell W_R^{\star} \to \ell \ell q q', \quad \ell = e \text{ or } \mu.$$







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Conclusion

Motivation for $\mathbf{g}_L \neq \mathbf{g}_R$

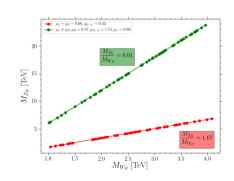
$$rac{1}{e^2} = rac{1}{g_L^2} + rac{1}{g_R^2} + rac{1}{g_{B-L}^2} \,,$$

Setting
$$\sin \phi = \frac{g_{B-L}}{\sqrt{g_R^2 + g_{B-L}^2}}$$
 and $\sin \theta_W = \frac{g_Y}{\sqrt{g_L^2 + g_Y^2}}$, we get

$$\tan \theta_W = \frac{g_R \sin \phi}{g_I} \le \frac{g_R}{g_I},$$

Theoretical constraint on
$$g_R$$
 gauge coupling

$$g_L \tan \theta_W \leq g_R$$





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Analysis

Observable	Constraints	Observable	Constraints
ΔB_s	[10.2-26.4]	ΔB_d	[0.294-0.762]
ΔM_K	$< 5.00 \times 10^{-15}$	$\frac{\Delta M_K}{\Delta M_K^{SM}}$	[0.7-1.3]
ϵ_{K}	$< 3.00 \times 10^{-3}$	$\frac{\epsilon}{\epsilon SM}$	[0.7-1.3]
$BR(B^0 o X_s \gamma)$	$[2.99, 3.87] \times 10^{-4}$	$\frac{BR(B^0 \to X_s \gamma)}{BR(B^0 \to X_s \gamma)_{SM}}$	[0.7-1.3]
M_h	[124, 126] GeV	$M_{H_{1,2}^{\pm\pm}}$	> 535 GeV
$M_{H_4,A_2,H_2^{\pm}}$	$>$ 4.75 \times M_{W_R}		

Table: Current experimental bounds imposed for consistent solutions.

Parameter	Scanned range	
v _R	[2.2, 20] TeV	
V_{CKM}^R : c_{12}^R , c_{13}^R , c_{23}^R	[-1, 1]	
$diag(\mathit{h}_{R}^{ij})$	[0.001, 1]	

$$M_{\mathcal{V}_R}^{ij} = h_R^{ij} v_R$$

$$V_{\text{CKM}}^R = \begin{bmatrix} c_{12}^R c_{13}^R & s_{12}^R c_{13}^R & s_{13}^R c_{13}^R \\ -s_{12}^R c_{23}^R - c_{12}^R c_{33}^R s_{13}^R s_{13}^{e^{i\delta}R} & c_{12}^R c_{23}^R - s_{12}^R c_{23}^R s_{13}^R e^{i\delta}R & s_{23}^R c_{13}^R \\ s_{12}^R s_{23}^R - c_{12}^R c_{23}^R s_{13}^R e^{i\delta}R & -c_{12}^R c_{23}^R - s_{13}^R c_{23}^R s_{13}^R e^{i\delta}R & c_{23}^R c_{13}^R \end{bmatrix}$$

Table: Scanned parameter space.



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Result

Scenario I: $M_{\mathcal{V}_R} > M_{\mathcal{W}_R}$ Scenario II: $M_{\mathcal{V}_R} < M_{\mathcal{W}_R}$ Correlating W_R and u mass bounds

Conclusion

$g_L \neq g_R = 0.37$, tan $\beta = 0.01$, $V_{\mathrm{CKM}}^L = V_{\mathrm{CKM}}^R$

Scenario I: $M_{\nu_P} > M_{W_P}$

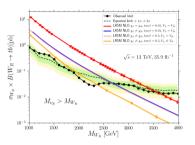
$$\left. egin{aligned} \mathsf{BR}(W_R o W_L h) \ \mathsf{BR}(W_R o W_L Z_L) \end{aligned}
ight.
ight. \left. egin{aligned} \mathsf{Invisible} \end{aligned} \ \mathsf{BR}(W_R o t ar{b}) \sim 32\% - 33\% \end{aligned}$$

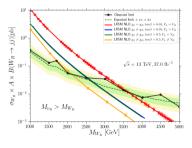
$$g_L
eq g_R =$$
 0.37, tan $eta =$ 0.5, $V_{
m CKM}^L = V_{
m CKM}^R$

$${\sf BR}(W_R o W_L h) \sim 1.95\% \ {\sf BR}(W_R o W_L Z_L) \sim 2.0\% \ {\sf BR}(W_R o t ar b) \sim 31.0\%$$
 - 31.8%

$$g_L
eq g_R = 0.37$$
, tan $eta = 0.5$, $V_{
m CKM}^L
eq V_{
m CKM}^R$

$${\sf BR}(W_R o tar b) \sim 20\%$$
 for high M_{W_R} (4 TeV) $\sim 29\%$ for low M_{W_R} (1.5 TeV)







The Left-Right Symmetric Model Charged Sector

at the LHC

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Result

 $M_{\mathcal{V}_R} > M_{W_R}$ Scenario II: $M_{\mathcal{V}_R} < M_{W_R}$ Correlating W_R and ν_R mass bounds

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Scenario II: $M_{\nu_R} < M_{W_R}$

$$g_L=g_R$$
 ,tan $eta=0.01,~V_{
m CKM}^L=V_{
m CKM}^R$

 ${
m BR}(W_R o
u_R \ell) \sim 5.8\%$ (each family) ${
m BR}(W_R o t ar b) \sim 26.5\%$ - 27.3%

$$g_L
eq g_R = 0.37$$
, tan $eta = 0.01$, $V_{
m CKM}^L = V_{
m CKM}^R$

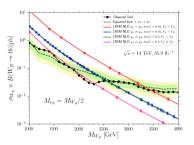
 ${\sf BR}(W_R o
u_R \ell) \sim 6.7\%$ (each family) ${\sf BR}(W_R o t ar b) \sim 25.7\%$ - 26.5%

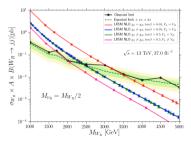
$$g_L
eq g_R =$$
 0.37, tan $eta =$ 0.5, $V_{
m CKM}^L = V_{
m CKM}^R$

 $\mathsf{BR}(W_R o
u_R \ell) \sim 6.7\%$ (each family) $\mathsf{BR}(W_R o W_L h) \sim 1.95\%$ $\mathsf{BR}(W_R o W_L Z_L) \sim 2.0\%$ $\mathsf{BR}(W_R o t ar{b}) \sim 24.8\%$ - 25.6%

$$g_L
eq g_R =$$
 0.37, tan $eta =$ 0.5, $V_{
m CKM}^L
eq V_{
m CKM}^R$

 ${
m BR}(W_R o t ar b) \sim 15.7\%$ for high M_{W_R} (4 TeV) $\sim 24.7\%$ for low M_{W_R} (1.5 TeV)







The Left-Right Symmetric Model

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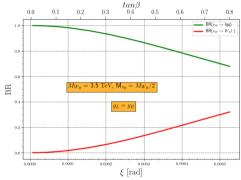
 $\begin{array}{l} \mathit{M}_{\mathcal{V}_R} > \mathit{M}_{\mathit{W}_R} \\ \text{Scenario II:} \\ \mathit{M}_{\mathcal{V}_R} < \mathit{M}_{\mathit{W}_R} \\ \text{Correlating } \mathit{W}_R \text{ and } \mathit{V}_R \\ \text{mass bounds} \end{array}$

Conclusion

Scenario II: $M_{\nu_R} < M_{W_R}$

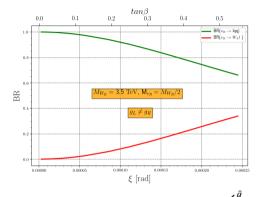
$$W_R \to \ell \nu_R \to \ell \ell W_R^* \to \ell \ell q q', \ \ell = e \text{ or } \mu.$$

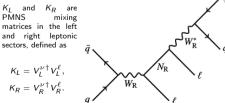
$$W_R \to \ell \nu_R \to \ell \ell W_L \to \ell \ell q q', \ \ell = e \text{ or } \mu.$$



$$\overline{\nu}W_L^{+\mu}\ell \longrightarrow \frac{i}{\sqrt{2}}\gamma^{\mu}\left(g_LP_LK_L\cos\xi - g_RP_RK_R\sin\xi\right)$$

$$\overline{
u}W_R^{+\mu}\ell \longrightarrow rac{i}{\sqrt{2}}\gamma^{\mu}\left(g_RP_RK_R\cos\xi-g_LP_LK_L\sin\xi
ight)$$







The Left-Right Symmetric Model Charged Sector

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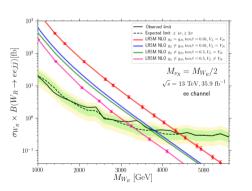
Results

 $M_{\mathcal{V}_R} > M_{\mathcal{W}_R}$ Scenario II: $M_{\mathcal{V}_R} < M_{\mathcal{W}_R}$ Correlating W_R and v_R mass bounds

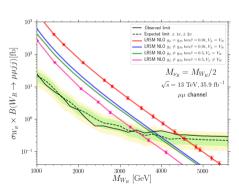
Conclusion

eejj final state

Scenario II: $M_{\nu_P} < M_{W_P}$



$\mu\mu$ jj final state





The Left-Right Symmetric Model

Charged Sector

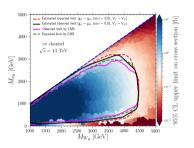
Motivatio

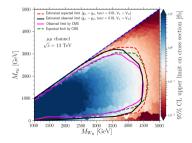
Results

 $M_{\nu_R} > M_{W_R}$ Scenario II: $M_{\nu_R} < M_{W_R}$ Correlating W_R and ν_R mass bounds

Conclusion

Correlating W_R and ν_R mass bounds





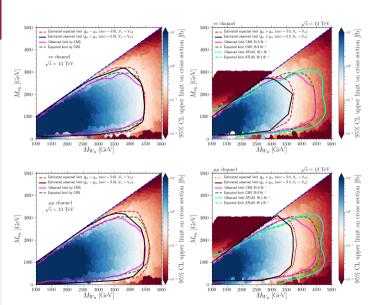


Symmetric Model

 $M_{\nu_{-}} > M_{\nu_{-}}$ $M_{\nu} < M_{W}$

Correlating $W_{\scriptscriptstyle D}$ and $\nu_{\scriptscriptstyle D}$ mass bounds

Correlating W_R and ν_R mass bounds





The Left-Right

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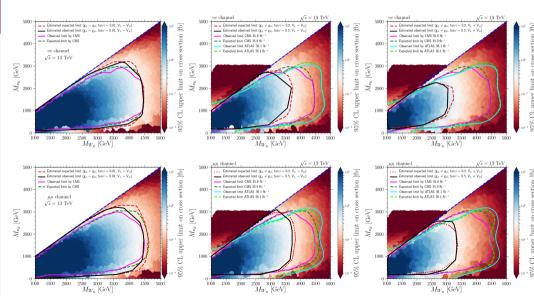
Result

Scenario II: $M_{\nu_R} > M_{W_R}$ Scenario II: $M_{\nu_R} < M_{W_R}$

Correlating W_R and u_R mass bounds

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Correlating W_R and ν_R mass bounds





The Left-Right Symmetric Model Charged Sector

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Scenario I: $M_{\mathcal{V}_R} > M_{W_R}$ Scenario II: $M_{\mathcal{V}_R} < M_{W_R}$ Correlating W_R and ν_R mass bounds

Conclusion

Outline

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- Motivation
- 4 Results

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Lower limits for M_{W_R} (GeV)		Exclusion
Expected	Observed	channel
Lxpected	Obscived	
3450	3600	$W_R o tb$
2700	2700	$W_R o tb$
2675	2675	$W_R o tb$
1940	2360	$W_R o tb$
3625	3620	$W_R o jj$
2700	2555	$W_R o jj$
2650	2500	$W_R o jj$
2010	2000	$W_R o jj$
	Expected 3450 2700 2675 1940 3625 2700 2650	Expected Observed 3450 3600 2700 2700 2675 2675 1940 2360 3625 3620 2700 2555 2650 2500

Table: Lower limits for M_{W_R} in GeV, when $M_{\nu_R} > M_{W_R}$.



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The Left-Right Symmetric Model Charged Sector

Motivation

 $\begin{array}{l} {\rm M}_{\nu_R} > {\rm M}_{W_R} \\ {\rm Scenario \ II:} \\ {\rm M}_{\nu_R} < {\rm M}_{W_R} \\ {\rm Correlating \ } W_R \ {\rm and \ } \nu_R \\ {\rm mass \ bounds} \end{array}$

Conclusion

Conclusion

Scenario II: $M_{ u_R} < M_{W_R}$	Lower limits for M_{W_R} (GeV)		Exclusion
	Expected	Observed	channel
$g_L=g_R$, tan $eta=0.01,~V_{ m CKM}^L=V_{ m CKM}^R$	4420	4420	$W_R o qqee$
$g_L eq g_R$, tan $eta = 0.01,~V_{ m CKM}^L = V_{ m CKM}^R$	3800	3800	$W_R o qqee$
$g_L eq g_R$, tan $eta = 0.5,~V_{ m CKM}^L = V_{ m CKM}^R$	3720	3725	$W_R o qqee$
$g_L eq g_R$, tan $eta = 0.5$, $V_{ ext{CKM}}^L eq V_{ ext{CKM}}^R$	3300	3100	$W_R o qqee$
$g_L=g_R$, tan $eta=0.01,~V_{ m CKM}^L=V_{ m CKM}^R$	4500	4420	$W_R o qq\mu\mu$
$g_L eq g_R$, tan $eta = 0.01$, $V_{ m CKM}^L = V_{ m CKM}^R$	3950	3800	$W_R o qq\mu\mu$
$g_L eq g_R$, tan $eta = 0.5, \; V_{ ext{CKM}}^L = V_{ ext{CKM}}^R$	3900	3750	$W_R o qq\mu\mu$
$g_L eq g_R$, tan $eta = 0.5, \ V_{ m CKM}^L eq V_{ m CKM}^R$	3400	3350	$W_R o qq\mu\mu$

Table: Lower limits for M_{W_R} in GeV when $M_{\nu_R} < M_{W_R}$.



The Left-Right Symmetric Model Charged Sector

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Result

Scenario I: $M_{\mathcal{V}_R} > M_{\mathcal{W}_R}$ Scenario II: $M_{\mathcal{V}_R} < M_{\mathcal{W}_R}$ Correlating W_R and ν mass bounds

Conclusion

	BM I : $M_{\nu_R} > M_{W_R}$	$\mathbf{BM II}: M_{\nu_R} < M_{W_R}$
m_{W_R} [GeV]	2557	3689
$m_{ u_R}$ [GeV]	16797	1838
$\sigma(pp o W_{R})$ [fb] @13 TeV	48.7	3.98
$\sigma(pp o W_R)$ [fb] @27 TeV	478.0	77.3
$BR(W_R o t \overline{b}) \ [\%]$	26.3	19.9
$BR(W_R o jj)$ [%]	58.6	45.8
$BR(W_R o u_R \ell) \ [\%]$	-	6.5 (each family)
$BR(W_R o h_1 W_L) \ [\%]$	1.8	1.5
$BR(W_R o W_L Z) \ [\%]$	2.0	1.6
$BR(u_R o \ell q q') \ [\%]$	-	65.3
$BR(u_R o W_L \ell) \ [\%]$	1.1×10^{-4}	33.1
$BR(u_R o W_R \ell) \ [\%]$	99.9	-

Table: Related Branching Ratios and Cross Sections for BM I and BM II.



The Left-Right Symmetric Model Charged Sector

V_R Mass Limits

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Results

Scenario I: $\begin{array}{l} M_{\mathcal{V}_R} > M_{W_R} \\ \text{Scenario II:} \\ M_{\mathcal{V}_R} < M_{W_R} \\ \text{Correlating } W_R \text{ and } \nu_R \\ \text{mass bounds} \end{array}$

Conclusion

Thank you!