

THE FLIPPED GENERATIONS

TEFO

UNIVERSITY OF COLIMA

WORKSHOP ON MULTI-Higgs MODELS
LISBOA - SEPTEMBER 4-7, 2018

OUR MOTIVATION

- MANY INTERESTING AND SOPHISTICATED IDEAS HAVE BEEN EXPLORED IN THE HOPE OF DESCRIBING NEW PHENOMENA AT HIGH ENERGIES

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SYMMETRIES (GAUGE,
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GUT'S

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- NO EVIDENCE SO FAR

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↳ QUESTIONS REMAIN

- γ -MASS
- FERMION MASS SPECTRUM
- BARYON ASYMMETRY OF THE UNIVERSE
- DARK MATTER

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- WHAT ARE THE ALTERNATIVES ?
 - ◆ QUIT PHYSICS
 - ◆ SWITCH TO CONDENSED MATTER — QUIT PHYSICS
 - ◆ KEEP TRYING
 - SOMETHING COMPLETELY NEW !!
 - GO BACK, SIMPLIFY AND PLAY

FIRST TAKE

- WE ADD FERMION "GENERATIONS"

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- WE ADD FERMION "GENERATIONS"

→ FORGET ABOUT UNIFICATION

THE MODEL

GAUGE SECTOR : $SU(3)_c \times SU(2)_w \times SU(2)_{hid} \times U(1)_X$

THE MODEL

Gauge Sector: $SU(3)_c \times SU(2)_w \times SU(2)_{hid} \times U(1)_X$



Assume:

$SU(3)_c \times SU(2)_w \times U(1)_Y$



$SU(3)_c \times U(1)_{em}$

$$Q = T_w^3 + T_{hid}^3 + X$$

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EXAMPLE : $H \sim (1, 2, 1, +1/2)$
 $H_{hid} \sim (1, 1, 2, -1/2)$
 $Q_L \sim (3, 2, 1, +1/6)$
 $Q'_R \sim (3, 1, 2, -1/6)$

Field	$SU(3)_C$	$SU(2)_w$	$SU(2)_{hid}$	$U(1)_X$
Q_L	3	2	1	+1/6
Q'_R	3	1	2	-1/6
U_R	3	1	1	+2/3
U'_L	3	1	1	-2/3
D_R	3	1	1	-1/3
D'_L	3	1	1	+1/3
L	1	2	1	-1/2
R'	1	1	2	+1/2
E_R	1	1	1	-1
E'_L	1	1	1	1
H	1	2	1	+1/2
H_{hid}	1	1	2	-1/2
\mathcal{B}	1	2	2	0

FLIPPED

$$L = \begin{pmatrix} Y_L \\ E_L \end{pmatrix}, \quad R = \begin{pmatrix} E'_R \\ \gamma_R \end{pmatrix}$$

$$Q_L = \begin{pmatrix} U_L \\ D_L \end{pmatrix}, \quad Q_R = \begin{pmatrix} D'_R \\ U'_R \end{pmatrix}$$

- No MIXING BETWEEN SM & FLIPPED FERMIONS

$$\begin{aligned}
 \mathcal{L}_Y = & y^u \bar{Q}_L \tilde{H} U_R + y^d \bar{Q}_L H D_R + y^E \bar{L} H E_R \\
 & - Z^u \bar{Q}'_R \tilde{H}_{hid} U'_L + Z^d \bar{Q}'_R H_{hid} D'_L + Z^E \bar{R}'_L H_{hid} E'_L \\
 & + h.c.
 \end{aligned}$$

BIDoublet B DOES NOT PARTICIPATE

- NEUTRINOS ARE MASSLESS AT TREE LEVEL,
INCLUDING ν_R IN THE FLIPPED SECTOR

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↳ LEPTON # CONSERVING DIM 5 OPERATOR

$$m_\nu^D \sim \frac{1}{\Lambda} (\bar{L} H) (\tilde{H}_{hid} R')$$

◆ "COMMUNICATION" BETWEEN SECTORS HAPPENS THROUGH PHOTON/GLUON AND $H^+ H_{hid}^+ H_{hid}$

↳ ELECTRICALLY CHARGED STABLE PARTICLES!

◆ BIDOUBLET B "FIXES" THAT

○ IF FLIPPED QUARKS DO NOT DECAY TO SM QUARKS \rightarrow NEW HADRONS m', p'

○ ASSUME $m_{m'} < m_{p'}$

$\Rightarrow p' \rightarrow m' \bar{e}' \nu_R$

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CHARGED
STABLE
PARTICLE!

- \mathcal{B} CAN GENERATE MIXING IN THE GAUGE SECTOR

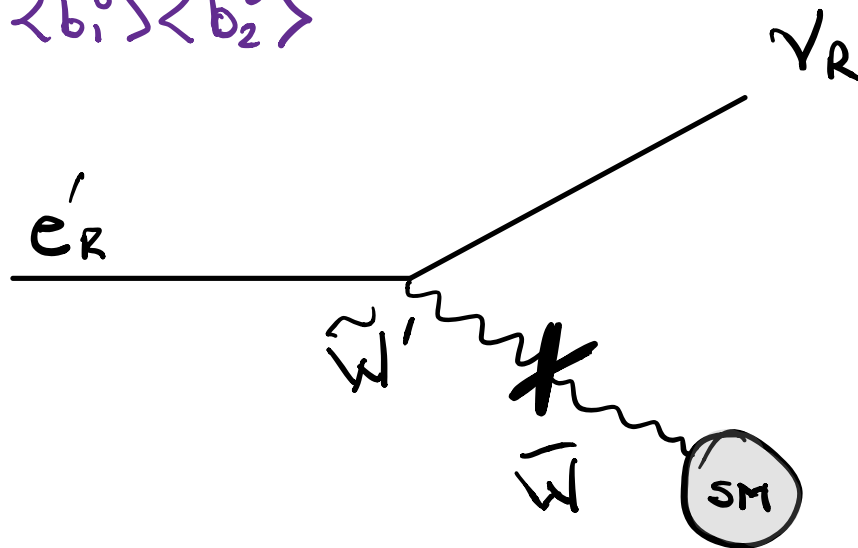
$$\mathcal{B} = \begin{pmatrix} b_1^0 & b_2^+ \\ b_1^- & b_2^0 \end{pmatrix}$$

$$\text{MIXING} \sim \langle b_1^0 \rangle \langle b_2^0 \rangle$$

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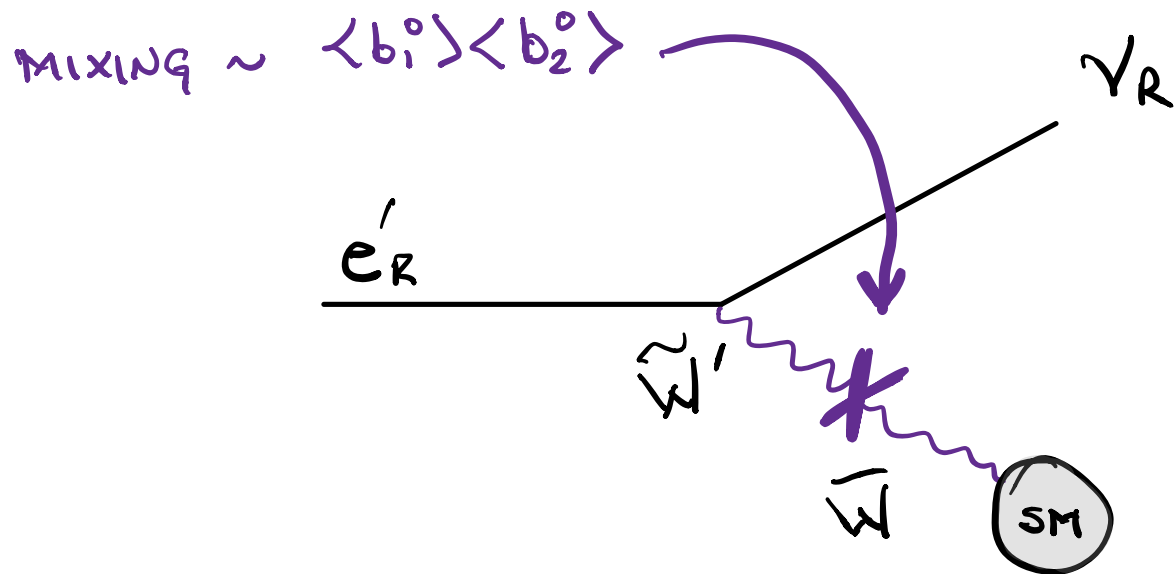
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JUST IN CASE YOU WANT TO SEE THE HIGGS
POTENTIAL

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$$\begin{aligned} V = & -\mu^2 H^\dagger H + \lambda (H^\dagger H)^2 - \mu'^2 H_{\text{hid}}^\dagger H_{\text{hid}} \\ & + \lambda' (H_{\text{hid}}^\dagger H_{\text{hid}})^2 + \lambda_{\#} H^\dagger H H_{\text{hid}}^\dagger H_{\text{hid}} \\ & + V_{\mathcal{B}}(H, H_{\text{hid}}) \end{aligned}$$

$$\begin{aligned}
V_{\mathcal{B},(H, H_{hid})} = & -\mu_B^2 \text{Tr}[\mathcal{B}^\dagger \mathcal{B}] - \tilde{\mu}_B^2 (\text{Tr}[\tilde{\mathcal{B}}\mathcal{B}^\dagger] + \text{Tr}[\tilde{\mathcal{B}}^\dagger \mathcal{B}]) \\
& + \lambda_B^{(1)} \text{Tr}[\mathcal{B}^\dagger \mathcal{B}]^2 + \lambda_B^{(2)} \left(\text{Tr}[\tilde{\mathcal{B}}\mathcal{B}^\dagger]^2 + \text{Tr}[\tilde{\mathcal{B}}^\dagger \mathcal{B}]^2 \right) \\
& + \lambda_B^{(3)} \text{Tr}[\tilde{\mathcal{B}}\mathcal{B}^\dagger] \text{Tr}[\tilde{\mathcal{B}}^\dagger \mathcal{B}] \\
& + \lambda_B^{(4)} \text{Tr}[\mathcal{B}^\dagger \mathcal{B}] \left(\text{Tr}[\tilde{\mathcal{B}}^\dagger \mathcal{B}] + \text{Tr}[\tilde{\mathcal{B}}\mathcal{B}^\dagger] \right) \\
& + \lambda_{BH} \text{Tr}[\mathcal{B}^\dagger \mathcal{B}] H^\dagger H + \lambda'_{BH} [\mathcal{B}^\dagger \mathcal{B}] H_{hid}^\dagger H_{hid} \\
& + \tilde{\lambda}_{BH} \left(\text{Tr}[\tilde{\mathcal{B}}\mathcal{B}^\dagger] + \text{Tr}[\tilde{\mathcal{B}}^\dagger \mathcal{B}] \right) H^\dagger H \\
& + \tilde{\lambda}'_{BH} \left(\text{Tr}[\tilde{\mathcal{B}}\mathcal{B}^\dagger] + \text{Tr}[\tilde{\mathcal{B}}^\dagger \mathcal{B}] \right) H_{hid}^\dagger H_{hid} \\
& + \left(\mu_{HBH} H^\dagger \mathcal{B} \tilde{H}_{hid} + \tilde{\mu}'_{HBH} H^\dagger \tilde{\mathcal{B}} \tilde{H}_{hid} + \text{H.c.} \right) .
\end{aligned}$$

$$\begin{aligned}
V = & -\mu^2 H^\dagger H + \lambda (H^\dagger H)^2 - \mu'^2 H_{\text{hid}}^\dagger H_{\text{hid}} \\
& + \lambda' (H_{\text{hid}}^\dagger H_{\text{hid}})^2 + \lambda_{\#} H^\dagger H H_{\text{hid}}^\dagger H_{\text{hid}} \\
& + V_B(H, H_{\text{hid}})
\end{aligned}$$



4 scalars (CP-even)

2 pseudoscalars (from B)

2 charged scalars

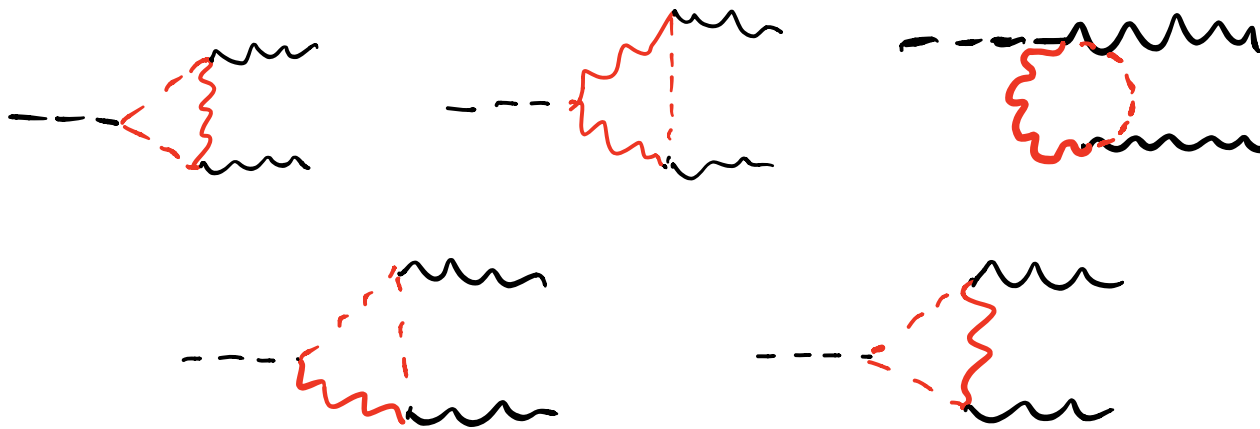
PHENO HIGHLIGHTS

- DUE TO SMALL MIXING THERE ARE NO EXPECTED CONTRIBUTIONS TO FCNC'S. (WE ARE CHECKING)
- CHARGED HIGGSSES AND $h \rightarrow \gamma\gamma$

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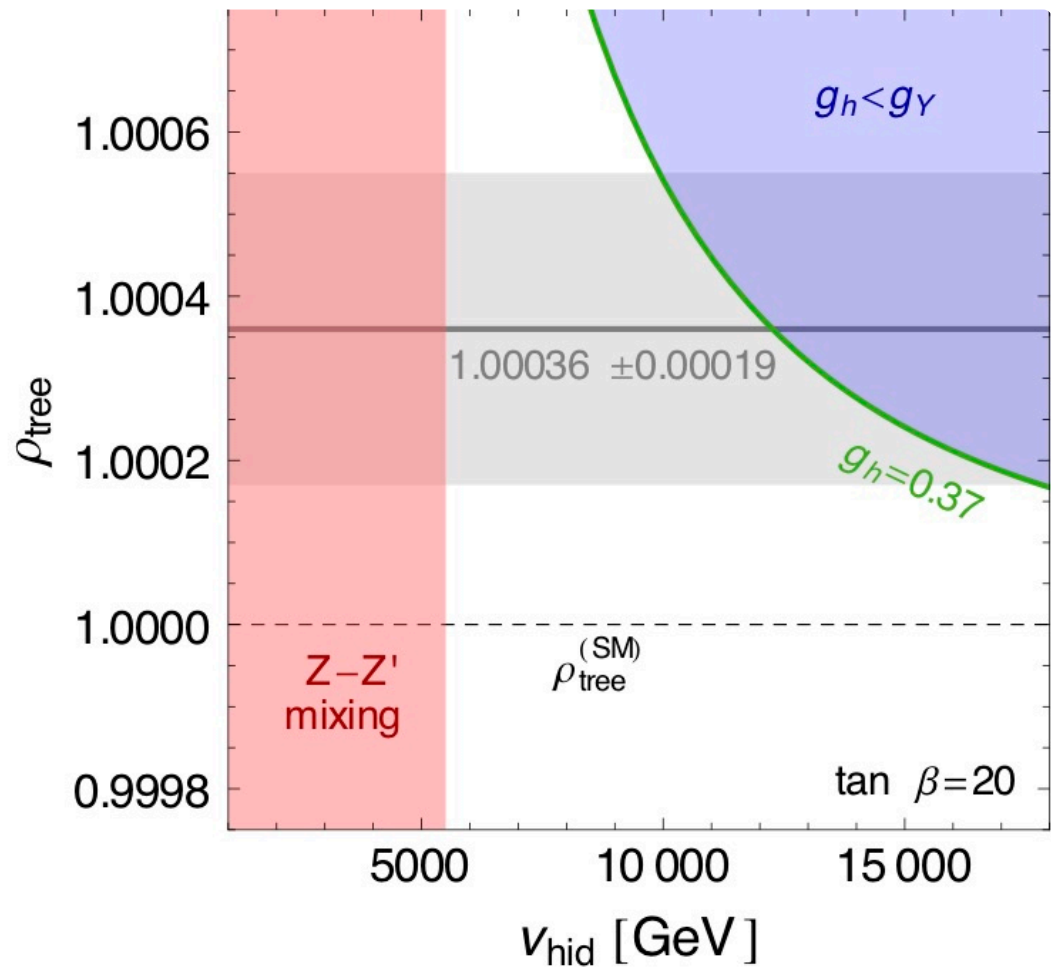
• ρ -PARAMETER

▶ H_{hid} CONTRIBUTES NON-TRIVIALY

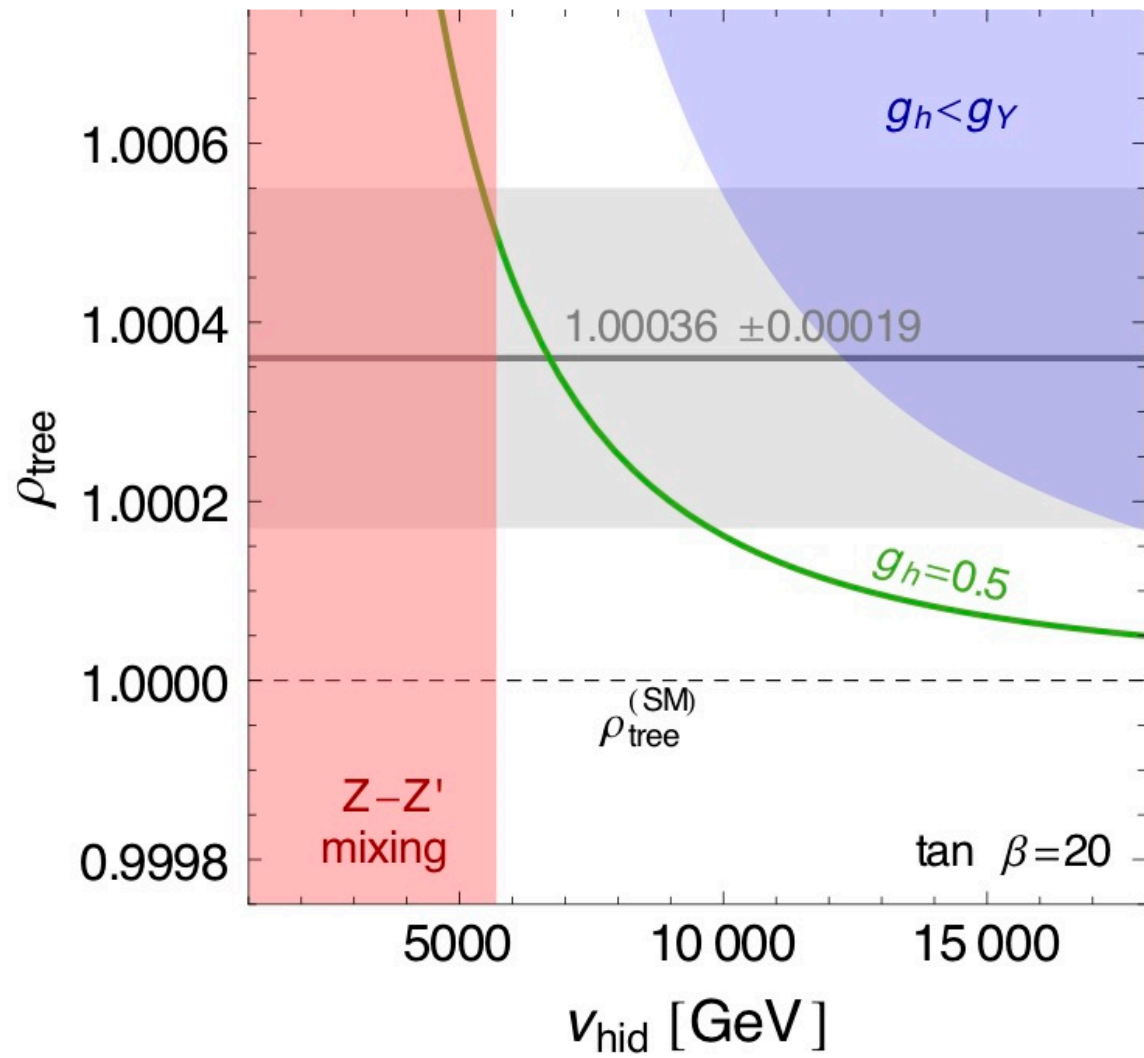
$$\rho_{\text{tree}} = 1 - \frac{\delta M_W^2}{M_{W, \text{cust}}^2} + \frac{\delta M_Z^2}{M_{Z, \text{cust}}^2} + \mathcal{O}(v^4/v_{\text{hid}}^4)$$

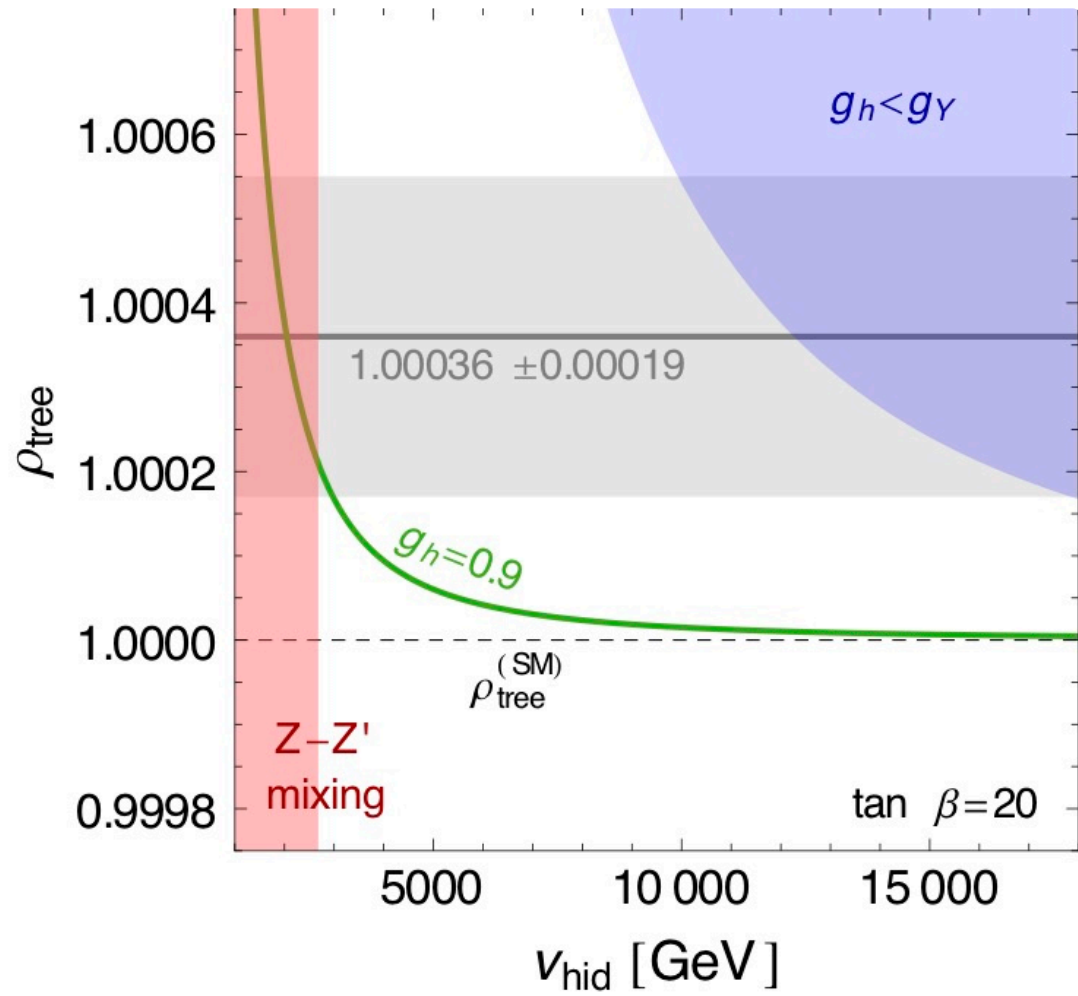
$$M_{W, \text{cust}}^2 = g^2 v^2/4, \quad M_{Z, \text{cust}}^2 = (g^2 + g_Y^2) v^2/4$$

$$C_W = \frac{g \sqrt{g_h^2 + g_x^2}}{\sqrt{g^2 (g_h^2 + g_x^2) + g_h^2 g_x^2}}; \quad g_x = \frac{g_Y g_h}{\sqrt{g_h^2 - g_Y^2}}$$



$\Rightarrow M_{W'} \lesssim 3.2 \text{ TeV}$





$\Rightarrow M_{\omega'} \sim 1 \text{ TeV}$

OUTLOOK

- ❏ CURRENTLY WORKING ON ANALYSIS AND "VARIATIONS"
- ❏ DARK MATTER?
- ❏ CAN WE SAY MORE ABOUT ν 's?

IN COLLABORATION WITH CARLOS ALVARADO 1807.01453
→ AND RAYMUNDO RAMOS (SOON!)

REGARDING v 's





DCPIHEP 2019 workshop:
Neutrino mass, mixing, and BSM physics

January 9 – 18 @ Comala, Colima

Workshop

The purpose of the workshop is to bring together people interested in BSM physics. Abundant time for discussion and actual work is contemplated. Organization of informal seminars and talks are encouraged as the workshop develops. If you are interested in leading a specific discussion session please send us the topic and hourly sessions needed. Information regarding other activities will be posted as it becomes available.

Registration

Please register and make questions by sending an email to **astuart at ucol.mx** There is no registration fee and travel/lodging info will be posted soon. The workshop will be held at the “Ex-Hacienda de Noguerras”, located in Comala, Colima.



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