ONE-LOOP NEUTRINO MASS IN $SU(5)$[*][◉]

Ilja Doršner

University of Split

Summer School and Workshop on the Standard Model and Beyond

September 8th, 2016

[*]I. Doršner, S. Fajfer, N. Košnik, work in progress.

[◉]Croatian Science Foundation (HRZZ) project # 7118

OUTLINE

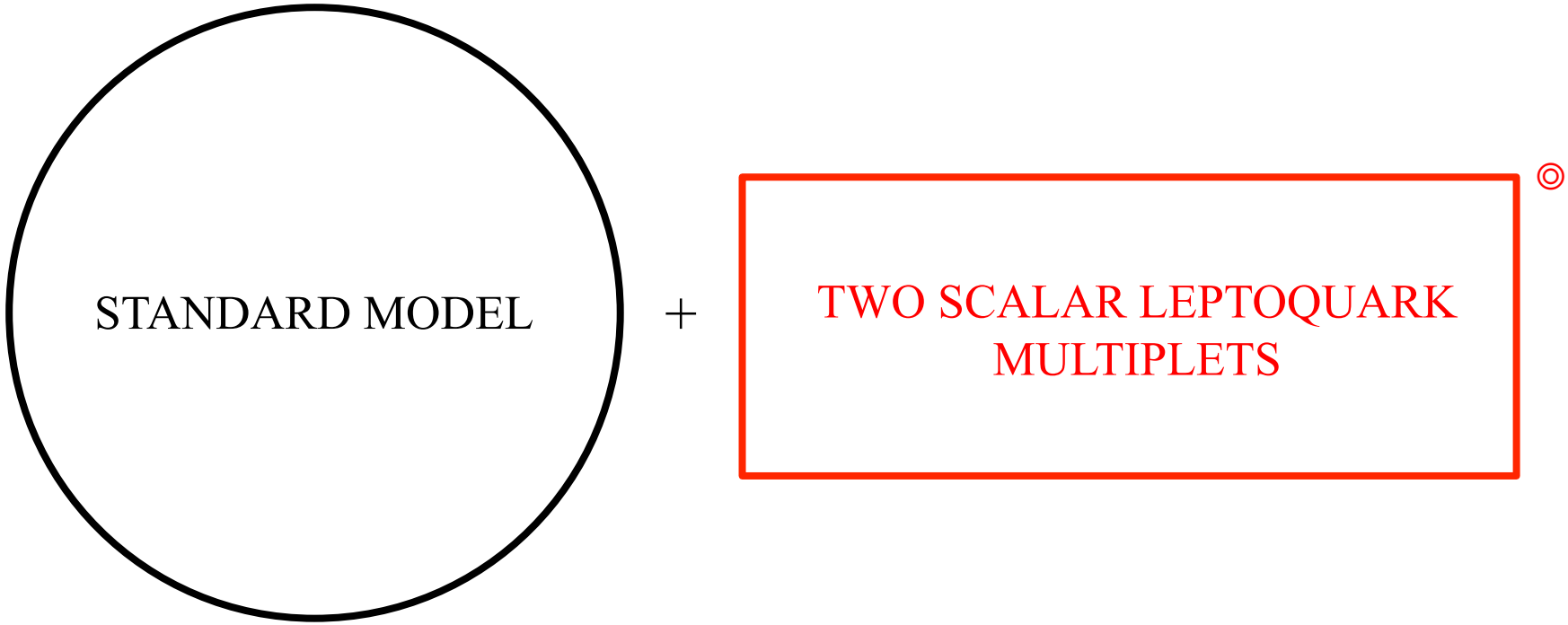
- **ONE-LOOP NEUTRINO MASS**
  A (NOT SO) BRIEF OVERVIEW

- **ONE-LOOP NEUTRINO MASS MECHANISM IN** $SU(5)$

- $SU(5)$ **VS.** $SO(10)$ **FRAMEWORK**
  A (VERY) BRIEF DISCUSSION OF POTENTIAL BENEFITS

- **CONCLUSIONS**

THE ONE-LOOP NEUTRINO MASS MECHANISM



◎C.-K. Chua, X.-G. He, W.-Y. P. Hwang, Phys. Lett. B479 (2000).

SCALAR LEPTOQUARKS [©]

$SU(3) \times SU(2) \times U(1)$ MULTIPLETS

SCALAR LEPTOQUARKS (LQs):

$$(\overline{\mathbf{3}}, \mathbf{3}, 1/3)$$

$$(\mathbf{3}, \mathbf{2}, 7/6)$$

$$(\mathbf{3}, \mathbf{2}, 1/6)$$

$$(\overline{\mathbf{3}}, \mathbf{1}, 1/3)$$

$$(\overline{\mathbf{3}}, \mathbf{1}, 4/3)$$

$$(\overline{\mathbf{3}}, \mathbf{1}, -2/3)$$

[©]I. Doršner, S. Fajfer, A. Greljo, J.F. Kamenik, N. Košnik, Phys. Rept. 641 (2016).

SCALAR LEPTOQUARKS

$SU(3) \times SU(2) \times U(1)$ MULTIPLETS

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$$S_3 \equiv \quad (\overline{\mathbf{3}}, \mathbf{3}, 1/3)$$

$$R_2 \equiv \quad (\mathbf{3}, \mathbf{2}, 7/6)$$

$$\tilde{R}_2 \equiv \quad (\mathbf{3}, \mathbf{2}, 1/6)$$

$$S_1 \equiv \quad (\overline{\mathbf{3}}, \mathbf{1}, 1/3)$$

$$\tilde{S}_1 \equiv \quad (\overline{\mathbf{3}}, \mathbf{1}, 4/3)$$

$$\bar{S}_1 \equiv \quad (\overline{\mathbf{3}}, \mathbf{1}, -2/3)$$

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◎W. Büchmuller *et al.*, Phys. Lett. B 191, 442 (1987). ⊙I. Doršner *et al.*, Phys. Rev. D 86, 015013 (2012).

SCALAR LEPTOQUARKS VS. ν MASS

ν MASS LQs: $\tilde{R}_2 + (S_3 \vee S_1)$

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SCALAR LEPTOQUARKS VS. p DECAY

p DECAY LQs: ($S_3,\ \tilde{R}_2,\ S_1,\ \tilde{S}_1,\ \bar{S}_1$)

SCALAR LEPTOQUARKS (LQs):

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ν MASS VS. p DECAY

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A(NOTHER) **WORD ABOUT NOMENCLATURE**

$$\mathcal{L} \supset -\tilde{y}_{2\,ij}^{RL} \bar{d}_R^i \tilde{R}_2^a \epsilon^{ab} L_L^{j,b}$$

a, b (= 1, 2) are $SU(2)$ indices

i, j (= 1, 2, 3) are flavor indices

$\tilde{y}_2^{RL}$ ≡ Yukawa coupling matrix

A WORD ABOUT NOMENCLATURE

$$\mathcal{L} \supset -\tilde{y}_{2\,ij}^{RL} \bar{d}_R^i \tilde{R}_2^a \epsilon^{ab} L_L^{j,b}$$

$$\mathcal{L} \supset -\tilde{y}_{2\,ij}^{RL} \bar{d}_R^i e_L^j \tilde{R}_2^{2/3} + (\tilde{y}_2^{RL} U)_{ij} \bar{d}_R^i \nu_L^j \tilde{R}_2^{-1/3}$$

a, b (= 1, 2) are $SU(2)$ indices

i, j (= 1, 2, 3) are flavor indices

$\tilde{y}_2^{RL}$ ≡ Yukawa coupling matrix

U ≡ Pontecorvo-Maki-Nakagawa-Sakata unitary mixing matrix

ONE-LOOP NEUTRINO MASS

$$\tilde{y}_2^{RL} \bar{d}_R \nu_L \tilde{R}_2^{-1/3}$$

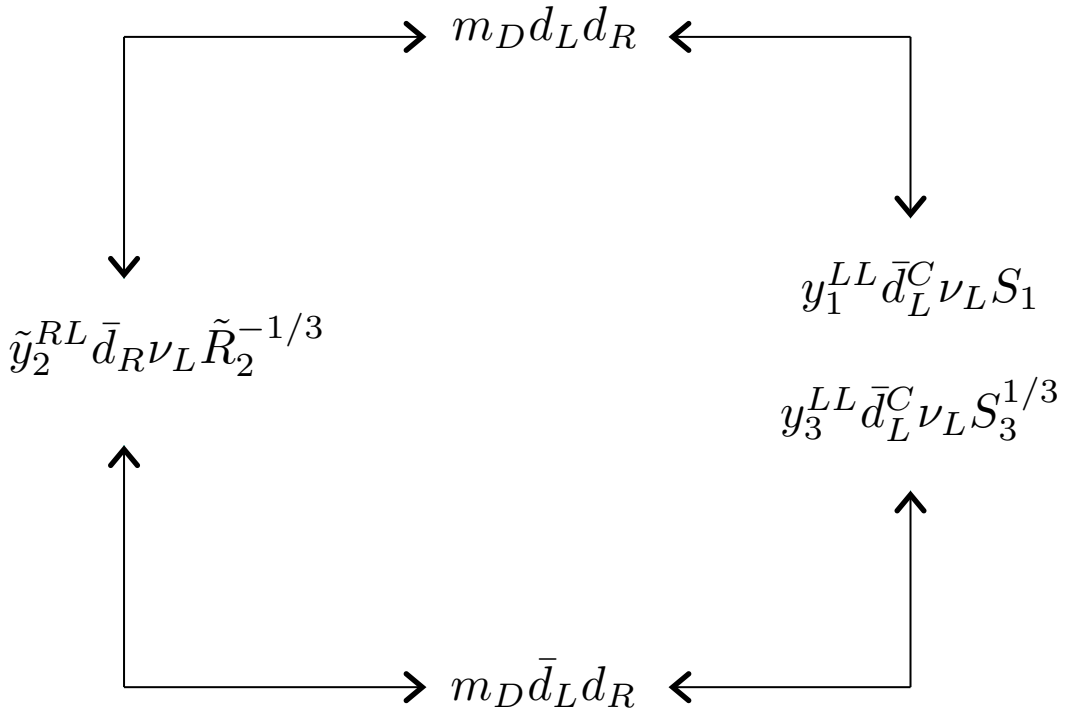
ONE-LOOP NEUTRINO MASS

$\tilde{y}_2^{RL} \bar{d}_R \nu_L \tilde{R}_2^{-1/3}$

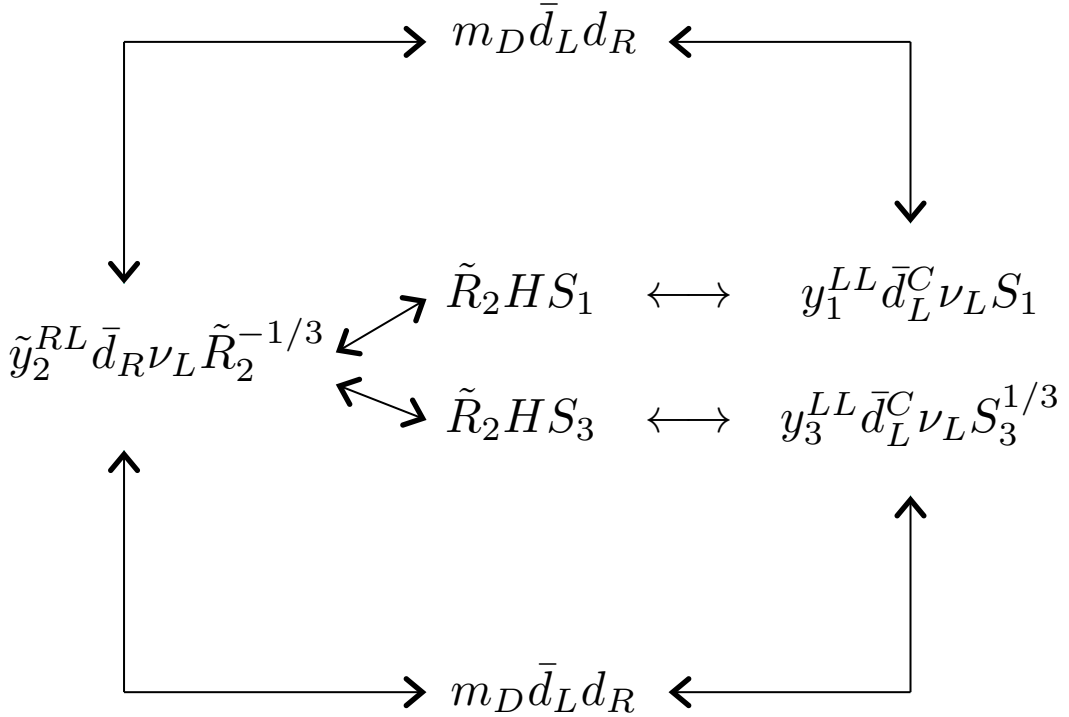
$y_1^{LL} \bar{d}_L^C \nu_L S_1$

$y_3^{LL} \bar{d}_L^C \nu_L S_3^{1/3}$

ONE-LOOP NEUTRINO MASS

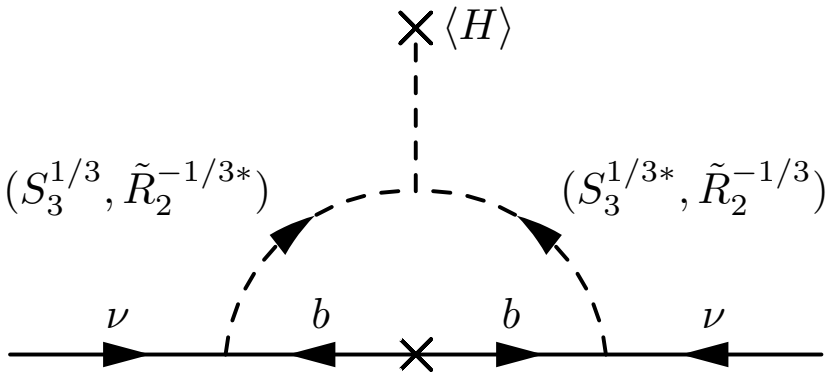


ONE-LOOP NEUTRINO MASS



$$H \equiv (\mathbf{1}, \mathbf{2}, -1/2)$$

ONE-LOOP NEUTRINO MASS



IMPORTANT ISSUES

WHAT HAPPENED WITH THE LQ DIQUARK COUPLINGS?

LQ MASSES ARE FREE PARAMETERS…

$\tilde{y}_2^{RL}$, y_1^{LL}, y_3^{LL} ARE ALL *A PRIORI* UNKNOWN MATRICES…

ONE-LOOP ν MASSES IN $SU(5)$

SCALAR LQs	$SU(5)$
$S_3 \equiv (\overline{\mathbf{3}}, \mathbf{3}, 1/3)$	$\overline{\mathbf{45}}$
$R_2 \equiv (\mathbf{3}, \mathbf{2}, 7/6)$	$\overline{\mathbf{45}}$
$\tilde{R}_2 \equiv (\mathbf{3}, \mathbf{2}, 1/6)$	$\mathbf{10}, \mathbf{15}$
$\tilde{S}_1 \equiv (\overline{\mathbf{3}}, \mathbf{1}, 4/3)$	$\mathbf{45}$
$S_1 \equiv (\overline{\mathbf{3}}, \mathbf{1}, 1/3)$	$\overline{\mathbf{5}}, \overline{\mathbf{45}}$
$\bar{S}_1 \equiv (\overline{\mathbf{3}}, \mathbf{1}, -2/3)$	$\mathbf{10}$

ONE-LOOP ν MASSES IN $SU(5)$

SCALAR REPRESENTATIONS IN $SU(5)$:

5	**10**	**15**	**45**
(S_1)	$(\tilde{R}_2)$	$(\tilde{R}_2)$	$(S_3,\ S_1)$
THE STANDARD MODEL SYMMETRY BREAKING	UNIFICATION OF GAUGE COUPLINGS	UNIFICATION	THE STANDARD MODEL SYMMETRY BREAKING
CHARGED FERMION MASSES		TYPE II SEE-SAW ν MASSES	CHARGED LEPTON & DOWN-TYPE QUARK MASSES

•H. Georgi, S. L. Glashow, Phys. Rev. Lett. 32 (1974). ◎H. Murayama, T. Yanagida, Mod. Phys. Lett. A7 (1992). ⊙I. Doršner, P. Fileviez Perez, Nucl. Phys. B723 (2005). ◆H. Georgi, C. Jarlskog., Phys. Lett. B86 (1979).

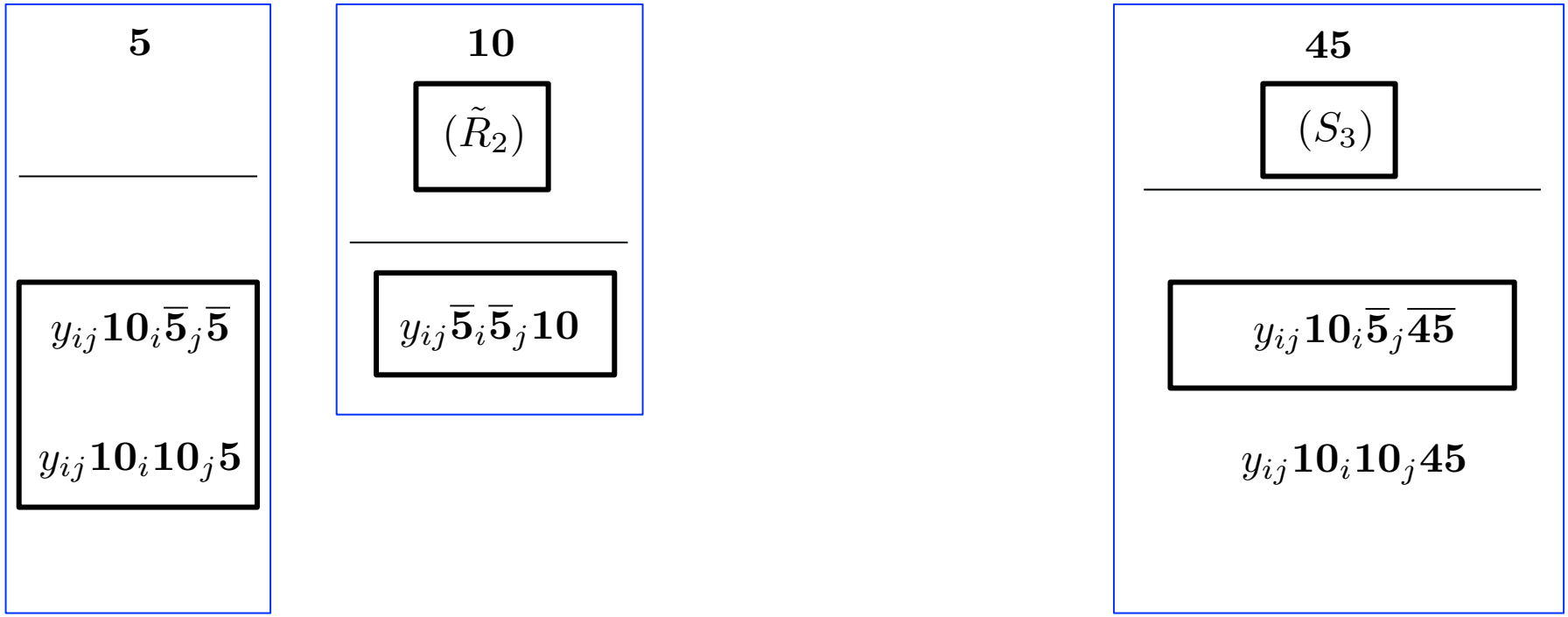
ONE-LOOP ν MASSES IN $SU(5)$

SCALAR REPRESENTATIONS IN $SU(5)$:

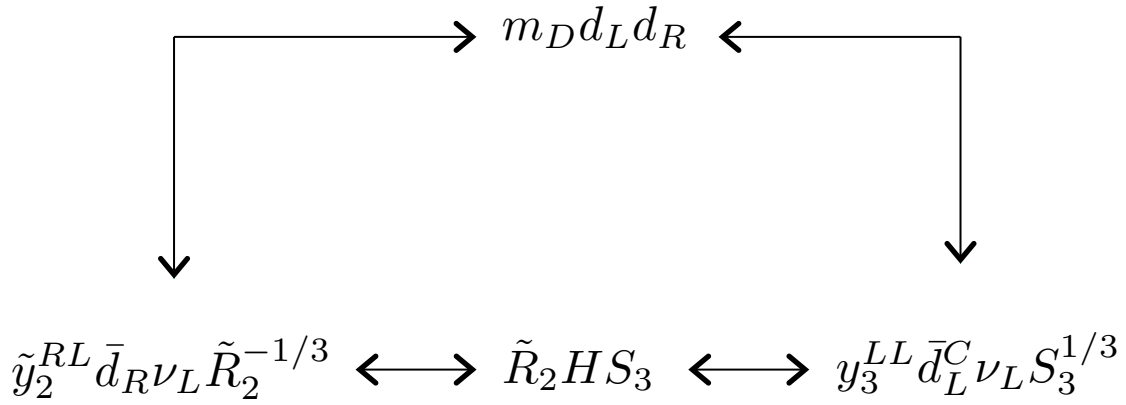
$\mathbf{5}$	$\mathbf{10}$	$\mathbf{15}$	$\mathbf{45}$
(S_1)	$(\tilde{R}_2)$	$(\tilde{R}_2)$	$(S_3,\, S_1)$
$y_{ij}\mathbf{10}_i\overline{\mathbf{5}}_j\overline{\mathbf{5}}$	$y_{ij}\overline{\mathbf{5}}_i\overline{\mathbf{5}}_j\mathbf{10}$	$y_{ij}\overline{\mathbf{5}}_i\overline{\mathbf{5}}_j\mathbf{15}$	$y_{ij}\mathbf{10}_i\overline{\mathbf{5}}_j\overline{\mathbf{45}}$
$y_{ij}\mathbf{10}_i\mathbf{10}_j\mathbf{5}$			$y_{ij}\mathbf{10}_i\mathbf{10}_j\mathbf{45}$

ONE-LOOP ν MASSES IN $SU(5)$

A POSSIBLE $SU(5)$ SET-UP:



ONE-LOOP NEUTRINO MASS



ONE-LOOP ν MASSES IN $SU(5)$

$$\mathbf{10}_i\overline{\mathbf{5}}_j\overline{\mathbf{5}} \quad \& \quad \mathbf{10}_i\overline{\mathbf{5}}_j\overline{\mathbf{45}}$$

$$m_D \bar{d}_L d_R$$

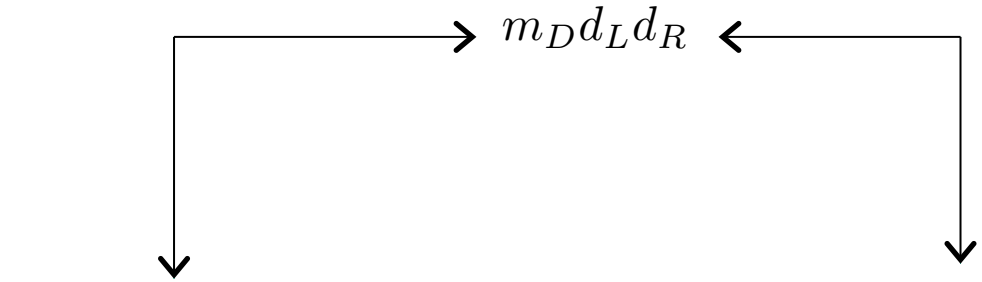
$$\tilde{y}_2^{RL}\bar{d}_R\nu_L\tilde{R}_2^{-1/3} \longleftrightarrow \tilde{R}_2 H S_3 \longleftrightarrow y_3^{LL}\bar{d}_L^C\nu_L S_3^{1/3}$$

$$\overline{\mathbf{5}}_i\overline{\mathbf{5}}_j\mathbf{10} \qquad \lambda\,\overline{\mathbf{5}}\mathbf{10}\overline{\mathbf{45}} \qquad \mathbf{10}_i\overline{\mathbf{5}}_j\overline{\mathbf{45}}$$

λ $\equiv$ dimensionful parameter

ONE-LOOP ν MASSES IN $SU(5)$

$$\mathbf{10}_i\overline{\mathbf{5}}_j\overline{\mathbf{5}} \quad \& \quad \mathbf{10}_i\overline{\mathbf{5}}_j\overline{\mathbf{45}}$$



$\overline{\mathbf{5}}_i\overline{\mathbf{5}}_j\mathbf{10}$ $\qquad$ $\lambda\,\overline{\mathbf{5}}\mathbf{10}\overline{\mathbf{45}}$ $\qquad$ $\mathbf{10}_i\overline{\mathbf{5}}_j\overline{\mathbf{45}}$

p DECAY

$$y_{ij}\mathbf{10}_i\overline{\mathbf{5}}_j\overline{\mathbf{45}}$$

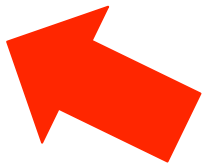
p DECAY

$$-y_{ij}\bar{u}^C_{L\,i}\nu_{L\,j}S_3^{-2/3}$$

$$2^{-1/2}y_{ij}\bar{u}^C_{L\,i}e_{L\,j}S_3^{1/3}$$

$$2^{-1/2}y_{ij}\bar{d}^C_{L\,i}\nu_{L\,j}S_3^{1/3}$$

$$y_{ij}\bar{d}^C_{L\,i}e_{L\,j}S_3^{+4/3}$$



$$y_{ij}\mathbf{10}_i\overline{\mathbf{5}}_j\overline{\mathbf{45}}$$ ◎

S_3 LEPTOQUARK MULTIPLET CAN BE LIGHT IF NEEDED

◎I. Doršner, S. Fajfer, N. Košnik, Phys. Rev. D 86, 015013 (2012).

A LIST OF BENEFITS

p DECAY CONSTRAINTS CAN BE ACCOMMODATED

LQ MASSES COULD BE CONSTRAINED THROUGH THE GAUGE COUPLING UNIFICATION…

RELEVANT YUKAWA COUPLING MATRICES ARE RELATED TO FERMION MASSES AND/OR POSSESS ADDITIONAL SYMMETRY. THIS CAN NOT ONLY REDUCE THE TOTAL NUMBER OF PARAMETERS BUT CAN HELP RELATE LEPTOQUARK DECAY PATTERNS TO NEUTRINO MASSES… ©

©P. Fileviez Perez, T. Han, Gui-Yu Huang, T. Li, K. Wang, Phys. Rev. D 78, 071301, (2008).

ONE-LOOP v MASSES IN $SO(10)$

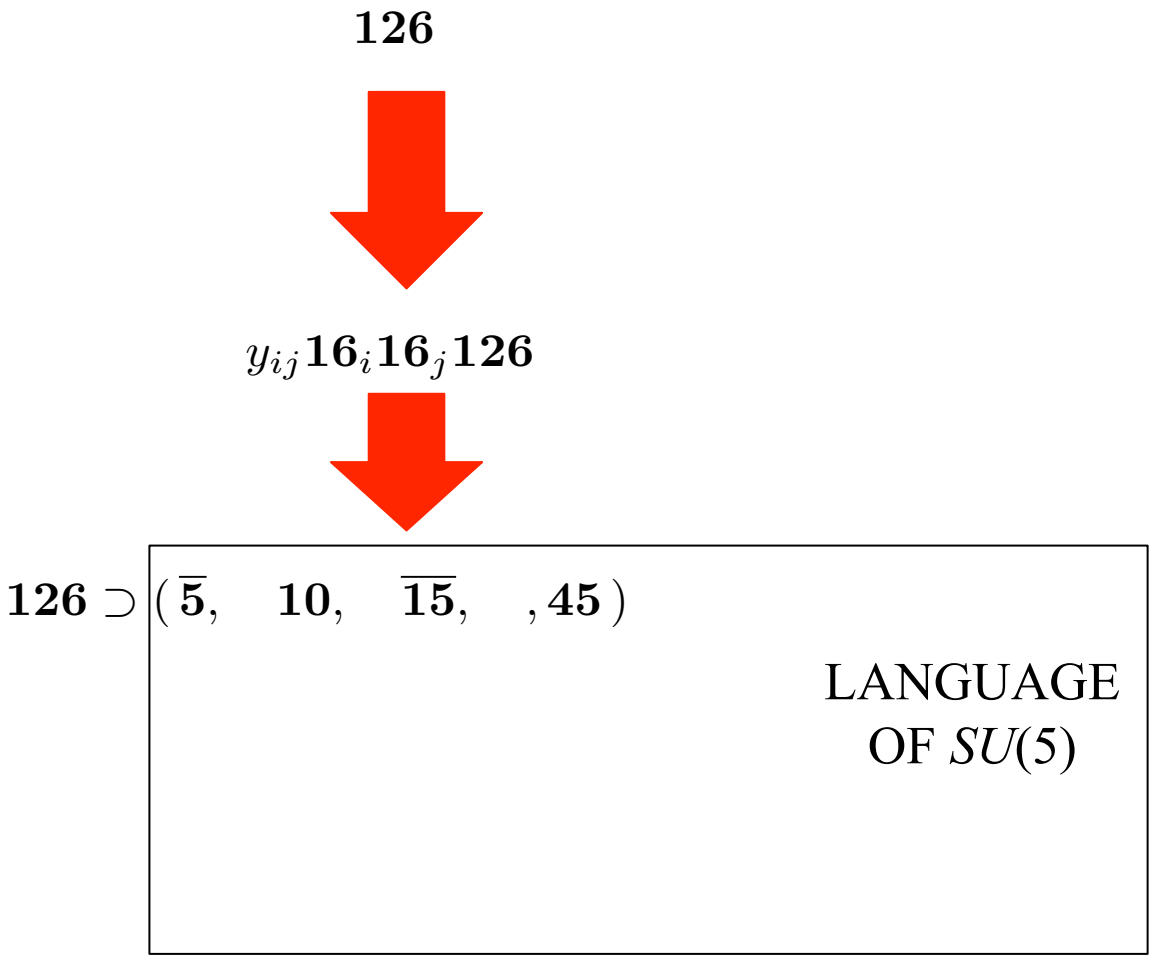
126
ALL LQs
THE STANDARD MODEL SYMMETRY BREAKING
FERMION MASSES
UNIFICATION OF GAUGE COUPLINGS

ONE-LOOP ν MASSES IN $SO(10)$

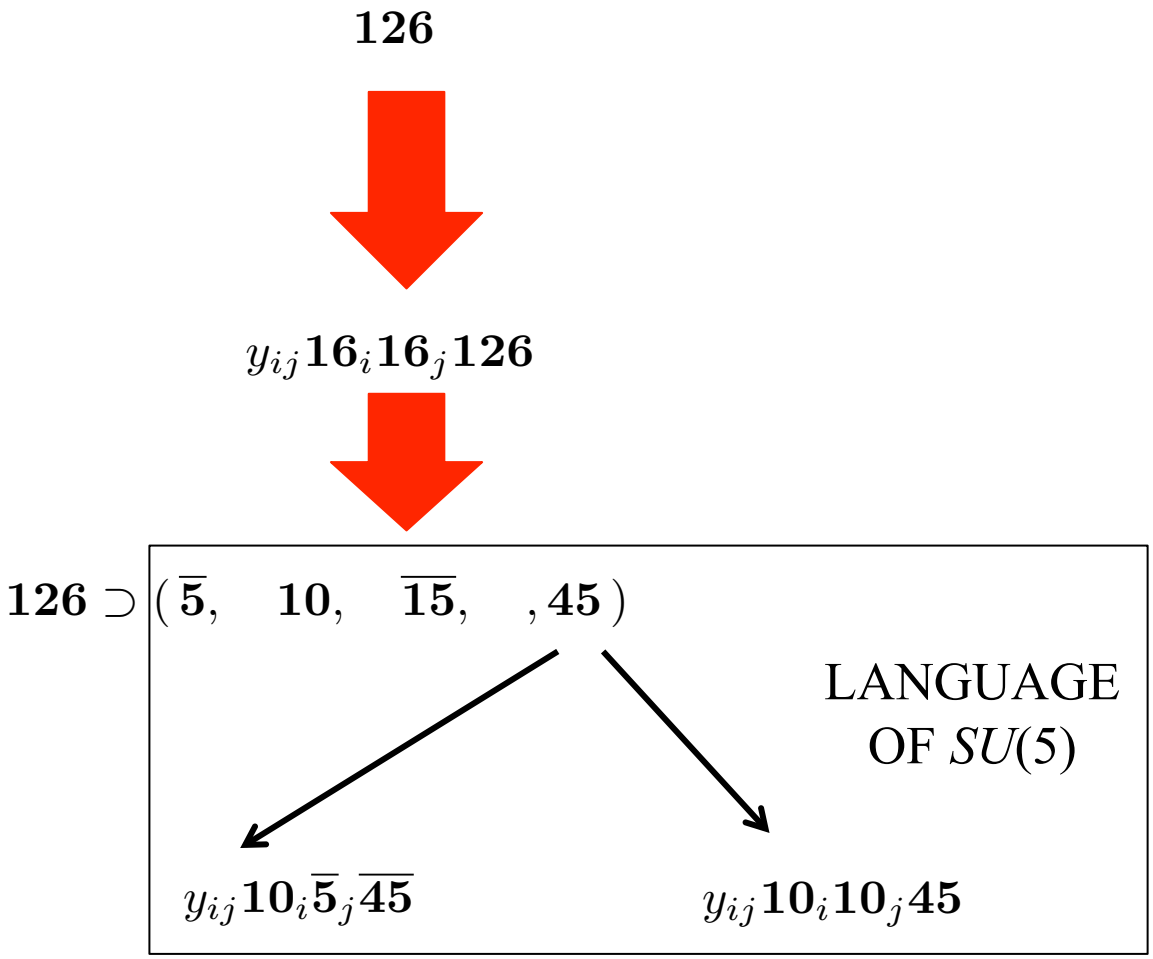
$\mathbf{126}$

$y_{ij}\mathbf{16}_i\mathbf{16}_j\mathbf{126}$

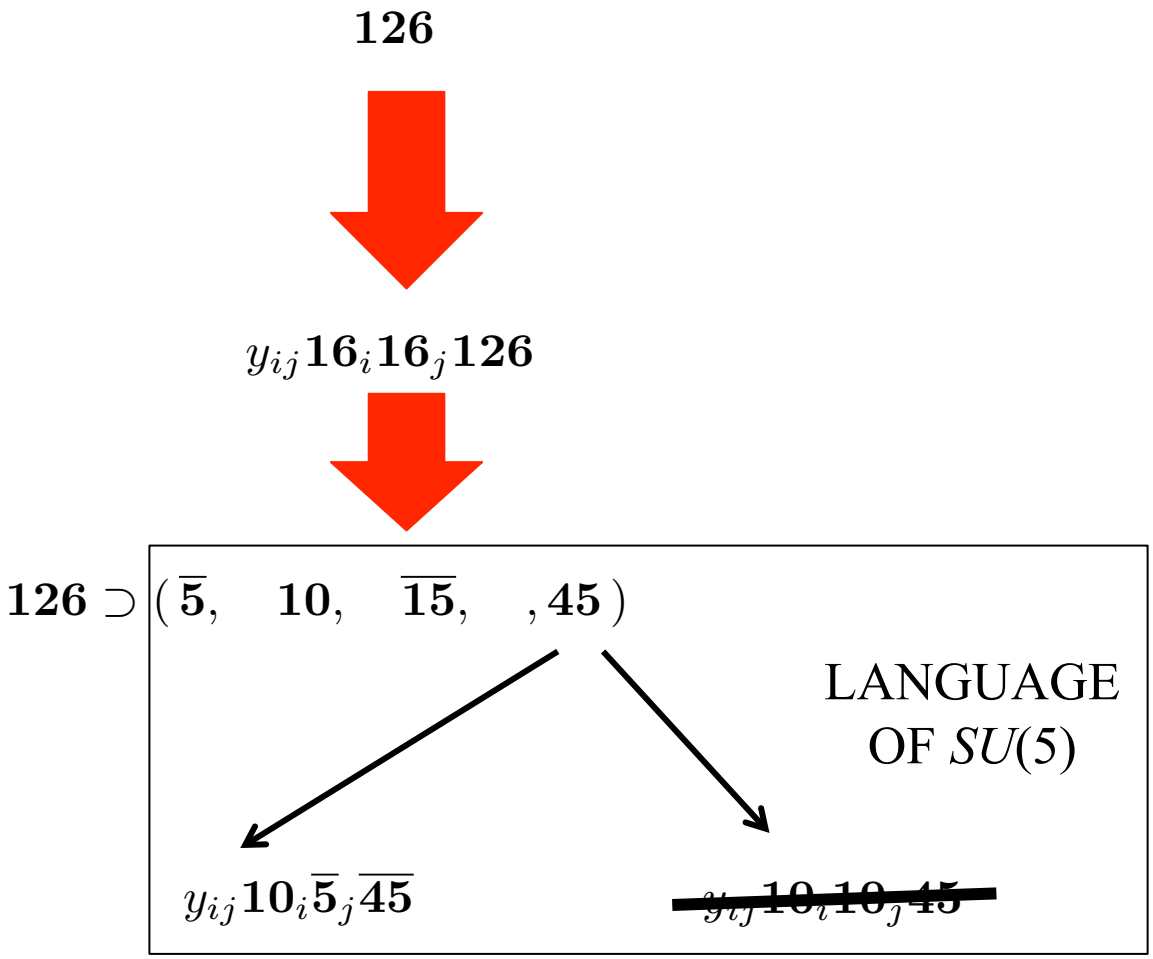
ONE-LOOP v MASSES IN $SO(10)$



ONE-LOOP v MASSES IN $SO(10)$



ONE-LOOP v MASSES IN $SO(10)$



CONCLUSIONS

SU(5) CAN ACCOMMODATE WITH EASE THE ONE-LOOP NEUTRINO MASS MECHANISM THAT IS BASED ON THE LEPTOQUARK MULTIPLET MIXING.

THE USE OF *SU*(5) CAN INCREASE PREDICTIVITY OF THE SET-UP. THIS COULD ESPECIALLY BE REFLECTED IN THE DECAY PATTERNS OF THE RELEVANT LEPTOQUARK MULTIPLETS.

THIS APPROACH TO NEUTRINO MASS ISSUE MIGHT ALSO BE IMPLEMENTED IN *SO*(10).

THANK YOU

dorsner@fesb.hr