Towards minimal $SU(5)$*

Ilja Doršner

University of Split

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OUTLINE

- **INTRODUCTION TO $SU(5)$ MODEL BUILDING**
- **A NOVEL $SU(5)$ PROPOSAL**
- **FITS & PREDICTIONS**
- **CONCLUSIONS**

INTRODUCTION TO $SU(5)$ MODEL BUILDING *

Model	Scalar content	Neutrino mass model
S1	ϕ_5, ϕ_{24}, ϕ_{10}	cA2,(cA1), (A4)
S2	ϕ_5, ϕ_{24}, ϕ_{15}	seesaw type II, (cA5)
S3	ϕ_5, ϕ_{24}, ϕ_{10}, ϕ_{40}	cA2,(cA1), (A4),(A2)
S4	ϕ_5, ϕ_{24}, ϕ_{10}, ϕ_{50}	cA2, (A1),(cA1), (A4)
S5	ϕ_5, ϕ_{24}, ϕ_{10}, ϕ_{70}^1, ϕ_{70}^2	cA2,(A5),(cA1), (A4)
S6	ϕ_5, ϕ_{24}, ϕ_{45}, ϕ_{10}	A0, cA2, cA4, (A4), (cA1), (cA3), (cA6)
S7	ϕ_5, ϕ_{24}, ϕ_{45}, ϕ_{15}	seesaw type II, (cA5), (cA7)
S8	ϕ_5, ϕ_{24}, ϕ_{45}, ϕ_{40}, ϕ_{50}	A3

*Christiane Klein, Manfred Lindner, Stefan Vogl, arXiv:1907.05328.

INTRODUCTION TO $SU(5)$ MODEL BUILDING *

Model	Scalar content	Fermionic content	Neutrino mass model
F1	ϕ_5, and ϕ_{24}	$\psi_{\bar{5}}$, ψ_{10}, ψ_1	seesaw type I
F2	ϕ_5, and ϕ_{24}	$\psi_{\bar{5}}$, ψ_{10}, ψ_{24}	seesaw type I+III, (cB8), (cC1)
F3	ϕ_5, ϕ_{24}, ϕ_{35}	$\psi_{\bar{5}}$, ψ_{10}, ψ_{15}, $\psi_{\overline{15}}$	B5
F4	ϕ_5, ϕ_{24}, ϕ_{45}	$\psi_{\bar{5}}$, ψ_{10}, ψ_1	seesaw type I
F5	ϕ_5, ϕ_{24}, ϕ_{45}	$\psi_{\bar{5}}$, ψ_{10}, ψ_{24}	seesaw type I+III, (cB8), (cB13), (cC1)
F6	ϕ_5, ϕ_{24}, ϕ_{45}	$\psi_{\bar{5}}$, ψ_{10}, ψ_{75}	seesaw type I, (cB8), (cB13), (cC1), (cC3)
F7	ϕ_5, ϕ_{24}, ϕ_{45}, ϕ_{40}	$\psi_{\bar{5}}$, ψ_{10}, ψ_5, $\psi_{\bar{5}}$	B3
F8	ϕ_5, ϕ_{24}, ϕ_{45}, ϕ_{40}	$\psi_{\bar{5}}$, ψ_{10}, ψ_{10}, $\psi_{\overline{10}}$	B2
F9	ϕ_5, ϕ_{24}, ϕ_{45}, ϕ_{40}	$\psi_{\bar{5}}$, ψ_{10}, ψ_{15}, $\psi_{\overline{15}}$	B4
F10	ϕ_5, ϕ_{24}, ϕ_{45}, ϕ_{40}	$\psi_{\bar{5}}$, ψ_{10}, ψ_{45}, $\psi_{\overline{45}}$	B3

*Christiane Klein, Manfred Lindner, Stefan Vogl, arXiv:1907.05328.

A NOVEL $SU(5)$ PROPOSAL

$$5_H,\ 24_H,\ 35_H,\ \overline{5}_{Fi},\ 10_{Fi},\ 15_F,\ \overline{15}_F, \qquad i = 1, 2, 3$$

A NOVEL $SU(5)$ PROPOSAL

$$15 \equiv \Sigma = \Sigma_1(1,3,1) + \Sigma_3(3,2,1/6) + \Sigma_6(6,1,-2/3)$$

$$24 \equiv \phi$$

$$\mathcal{L}_\Sigma \supset M_\Sigma \Sigma\overline{\Sigma} + y\ \Sigma\phi\overline{\Sigma}$$

$$M_{\Sigma_1} = M_\Sigma + \frac{1}{2}\sqrt{\frac{3}{5}} y V_{24} \equiv M_0$$

$$M_{\Sigma_3} = M_\Sigma + \frac{1}{4\sqrt{15}} y V_{24} \equiv M_0 - \frac{1}{4}\sqrt{\frac{5}{3}} y V_{24}$$

$$M_{\Sigma_6} = M_\Sigma - \frac{1}{\sqrt{15}} y V_{24} \equiv M_0 - \frac{1}{2}\sqrt{\frac{5}{3}} y V_{24}$$

A NOVEL $SU(5)$ PROPOSAL

$$35 \equiv \Phi = \Phi_1(1,4,-3/2) + \Phi_3(\overline{3},3,-2/3) + \Phi_6(\overline{6},2,1/6) + \Phi_{10}(\overline{10},1,1)$$

$$24 \equiv \phi$$

$$\mathcal{L}_\Phi \supset \mu_{35}^2 \Phi\Phi^* + \mu'_{35}\Phi^{\alpha\beta\gamma}\Phi^*{}_{\delta\alpha\beta}\phi^\delta_\gamma + \lambda\left(\Phi\Phi^*\right)\phi^2 + \lambda_1\Phi^{\alpha\beta\gamma}\Phi^*{}_{\alpha ab}\phi^a_\beta\phi^b_\gamma + \lambda_2\Phi^{\alpha\beta b}\Phi^*{}_{\alpha\beta c}\phi^a_b\phi^c_a$$

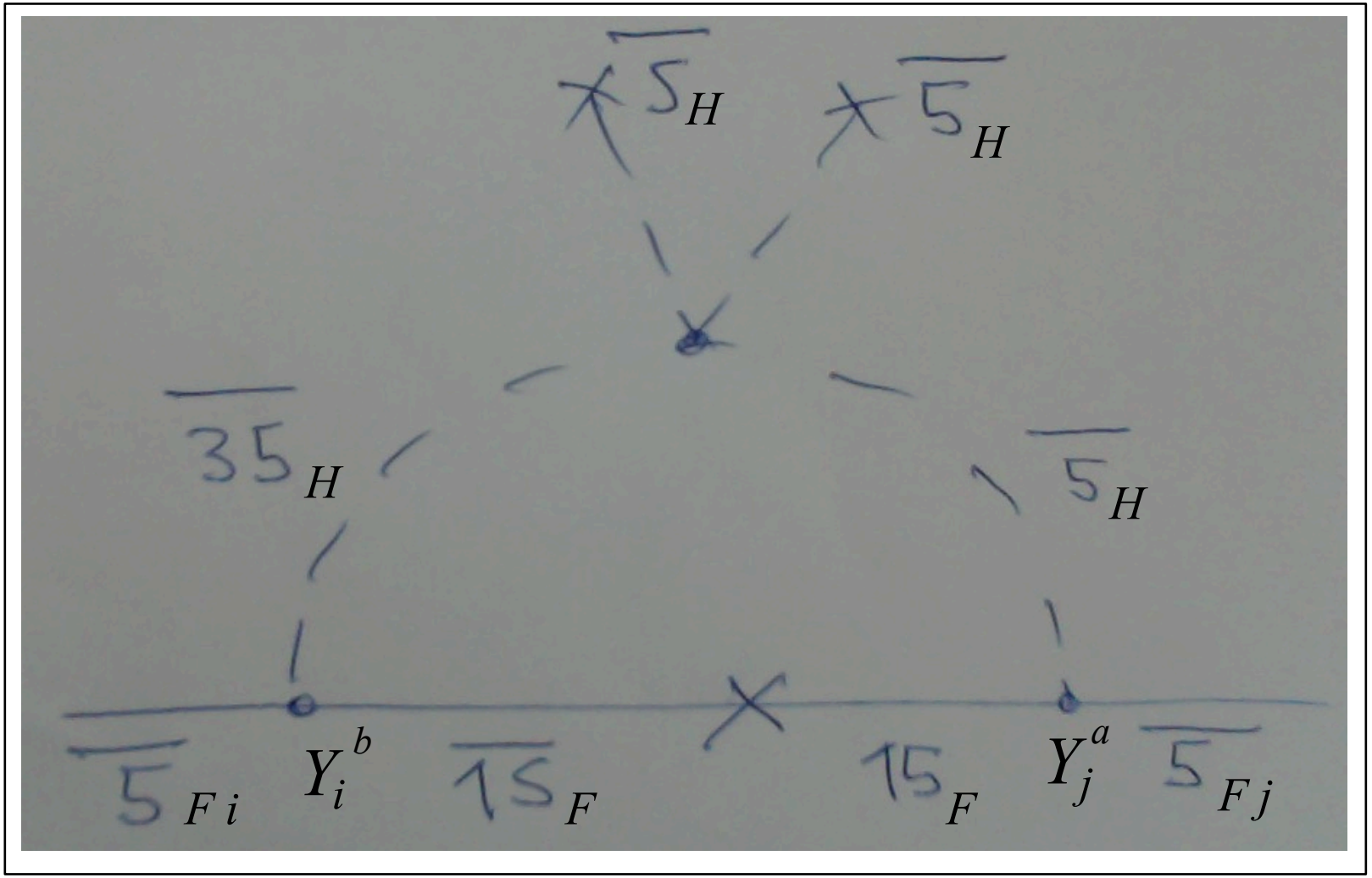
$$M^2_{\Phi_1} = \mu^2{}_{35} + \frac{\lambda V_{24}^2}{2} + \frac{3}{20}\lambda_1 V_{24}^2 + \frac{3}{20}\lambda_2 V_{24}^2 + \frac{1}{2}\sqrt{\frac{3}{5}}V_{24}\mu'_{35} \equiv M_1^2$$

$$M^2_{\Phi_3} = \mu^2{}_{35} + \frac{\lambda V_{24}^2}{2} - \frac{1}{60}\lambda_1 V_{24}^2 + \frac{11}{90}\lambda_2 V_{24}^2 + \frac{2V_{24}\mu'_{35}}{3\sqrt{15}} \equiv M_3^2$$

$$M^2_{\Phi_6} = \mu^2{}_{35} + \frac{\lambda V_{24}^2}{2} - \frac{2}{45}\lambda_1 V_{24}^2 + \frac{17}{180}\lambda_2 V_{24}^2 - \frac{V_{24}\mu'_{35}}{6\sqrt{15}} \equiv M_6^2$$

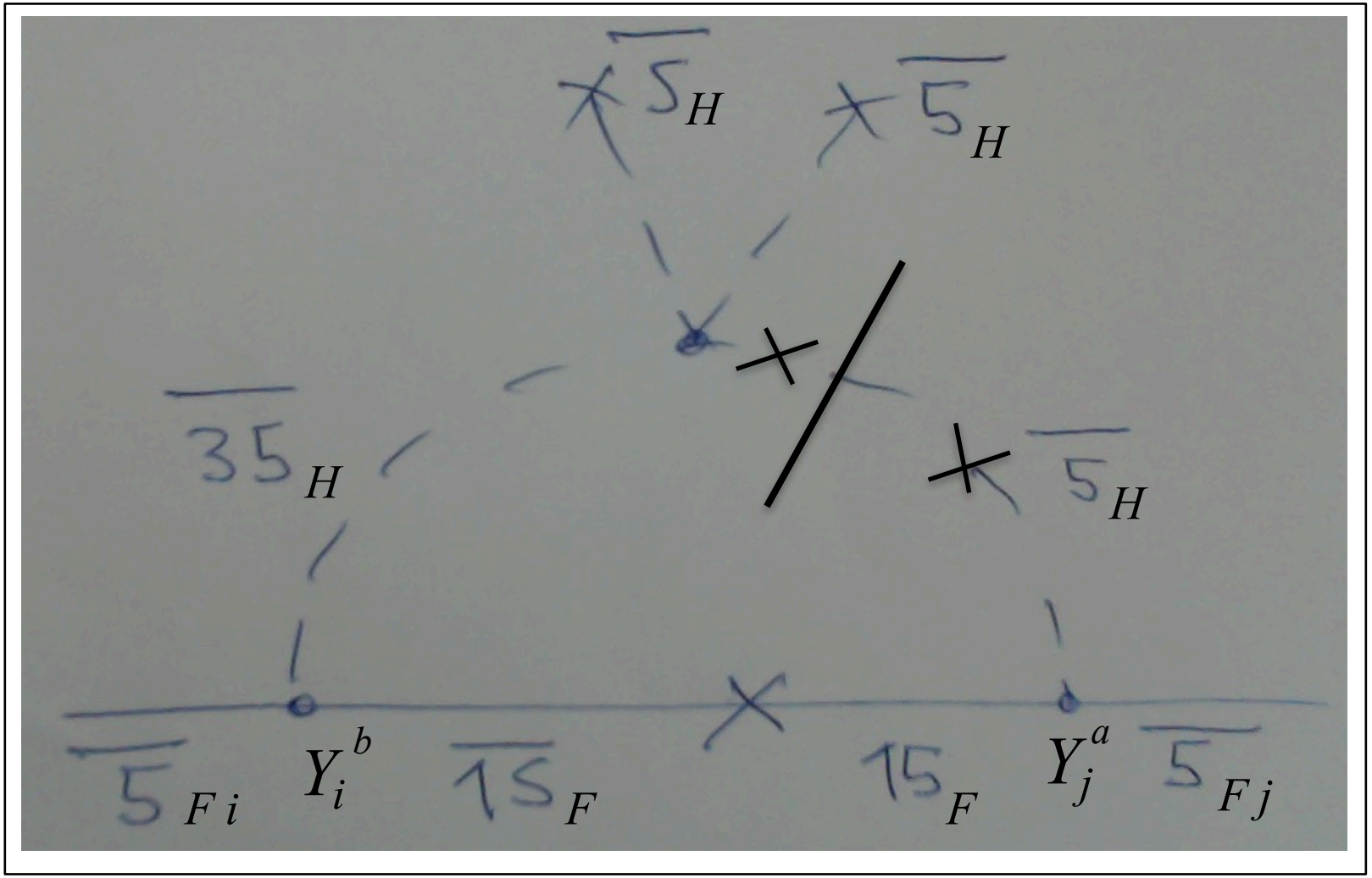
$$M^2_{\Phi_{10}} = M_1^2 - 3M_3^2 + 3M_6^2$$

A NOVEL *SU*(5) PROPOSAL



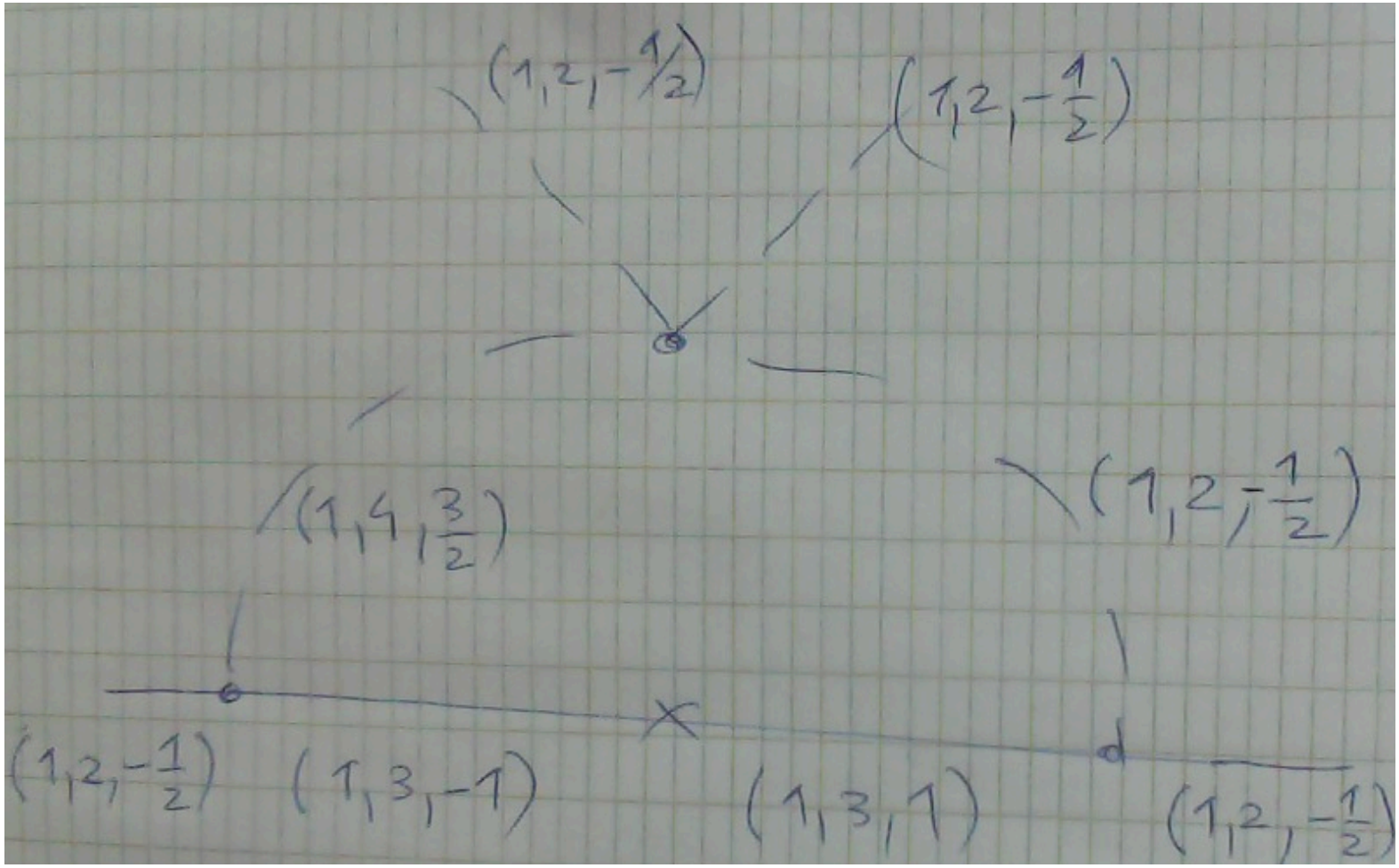
$$\mathcal{L} \supset \lambda' \, 5_H 5_H 5_H 35_H + Y_i^a \, 15_F \overline{5}_{Fi} 5_H^* + Y_i^b \, \overline{15}_F \overline{5}_{Fi} 35_H^*$$

A NOVEL $SU(5)$ PROPOSAL



$$35 \equiv \Phi = \Phi_1(1,4,-3/2) + \Phi_3(\overline{3},3,-2/3) + \Phi_6(\overline{6},2,1/6) + \Phi_{10}(\overline{10},1,1)$$

A NOVEL $SU(5)$ PROPOSAL



$$\mathcal{M}^{\nu}_{ij} \sim \frac{\lambda' v_H^2}{16\pi^2}(Y_i^a Y_j^b + Y_i^b Y_j^a)\frac{M_{\Sigma_1}}{M^2_{\Sigma_1} - M^2_{\Phi_1}} \log\left(\frac{M^2_{\Sigma_1}}{M^2_{\Phi_1}}\right)$$

A NOVEL $SU(5)$ PROPOSAL

$$\mathcal{M}^{\nu}_{ij} \sim m_0 \begin{pmatrix} 2Y_1^a Y_1^b & Y_2^a Y_1^b + Y_1^a Y_2^b & Y_3^a Y_1^b + Y_1^a Y_3^b \\ Y_2^a Y_1^b + Y_1^a Y_2^b & 2Y_2^a Y_2^b & Y_3^a Y_2^b + Y_2^a Y_3^b \\ Y_3^a Y_1^b + Y_1^a Y_3^b & Y_3^a Y_2^b + Y_2^a Y_3^b & 2Y_3^a Y_3^b \end{pmatrix}$$

$$\mathcal{M}^{\nu}_{ij} \sim \frac{\lambda' v_H^2}{16\pi^2}(Y_i^a Y_j^b + Y_i^b Y_j^a)\frac{M_{\Sigma_1}}{M_{\Sigma_1}^2 - M_{\Phi_1}^2}\log\left(\frac{M_{\Sigma_1}^2}{M_{\Phi_1}^2}\right)$$

A NOVEL $SU(5)$ PROPOSAL *

$$\begin{aligned}\mathcal{L} \supset\ & Y^d_{ij} 10_{Fi} \bar{5}_{Fj} 5^*_H + Y^u_{ij} 10_{Fi} 10_{Fj} 5_H \\ & + Y^a_i 15_F \bar{5}_{Fi} 5^*_H + Y^b_i \overline{15}_F \bar{5}_{Fi} 35^*_H + Y^c_i 10_{Fi} \overline{15}_F 24_H \\ & + M_\Sigma \overline{15}_F 15_F + y\ \overline{15}_F 15_F 24_H\end{aligned}$$

$$15 \equiv \Sigma = \Sigma_1(1,3,1) + \Sigma_3(3,2,1/6) + \Sigma_6(6,1,-2/3)$$

*Noriyuki Oshimo, arXiv:0907.3400.

A NOVEL $SU(5)$ PROPOSAL *

$$\begin{aligned}\mathcal{L} \supset\ & Y^d_{ij} 10_{Fi} \overline{5}_{Fj} 5^*_H + Y^u_{ij} 10_{Fi} 10_{Fj} 5_H \\ & + Y^a_i 15_F \overline{5}_{Fi} 5^*_H + Y^b_i \overline{15}_F \overline{5}_{Fi} 35^*_H + Y^c_i 10_{Fi} \overline{15}_F 24_H \\ & + M_\Sigma \overline{15}_F 15_F + y\ \overline{15}_F 15_F 24_H\end{aligned}$$

$$M_u = \left(\mathbb{I} + \frac{5}{48} \frac{V^2_{GUT}}{M^2_{\Sigma_3}} \widetilde{Y}^c \right)^{-\frac{1}{2}} \frac{1}{\sqrt{2}} v_5 Y^u$$

$$M_d = \left(\mathbb{I} + \frac{5}{48} \frac{V^2_{GUT}}{M^2_{\Sigma_3}} \widetilde{Y}^c \right)^{-\frac{1}{2}} \left(\frac{1}{\sqrt{2}} v^*_5 Y^d + \frac{1}{4} \sqrt{\frac{5}{3}} \frac{1}{\sqrt{2}} \frac{v^*_5 V_{GUT}}{M_{\Sigma_3}} \widetilde{Y}^{ca} \right)$$

$$M_e = \frac{1}{\sqrt{2}} v^*_5 Y^{dT}$$

*Noriyuki Oshimo, arXiv:0907.3400.

A NOVEL $SU(5)$ PROPOSAL

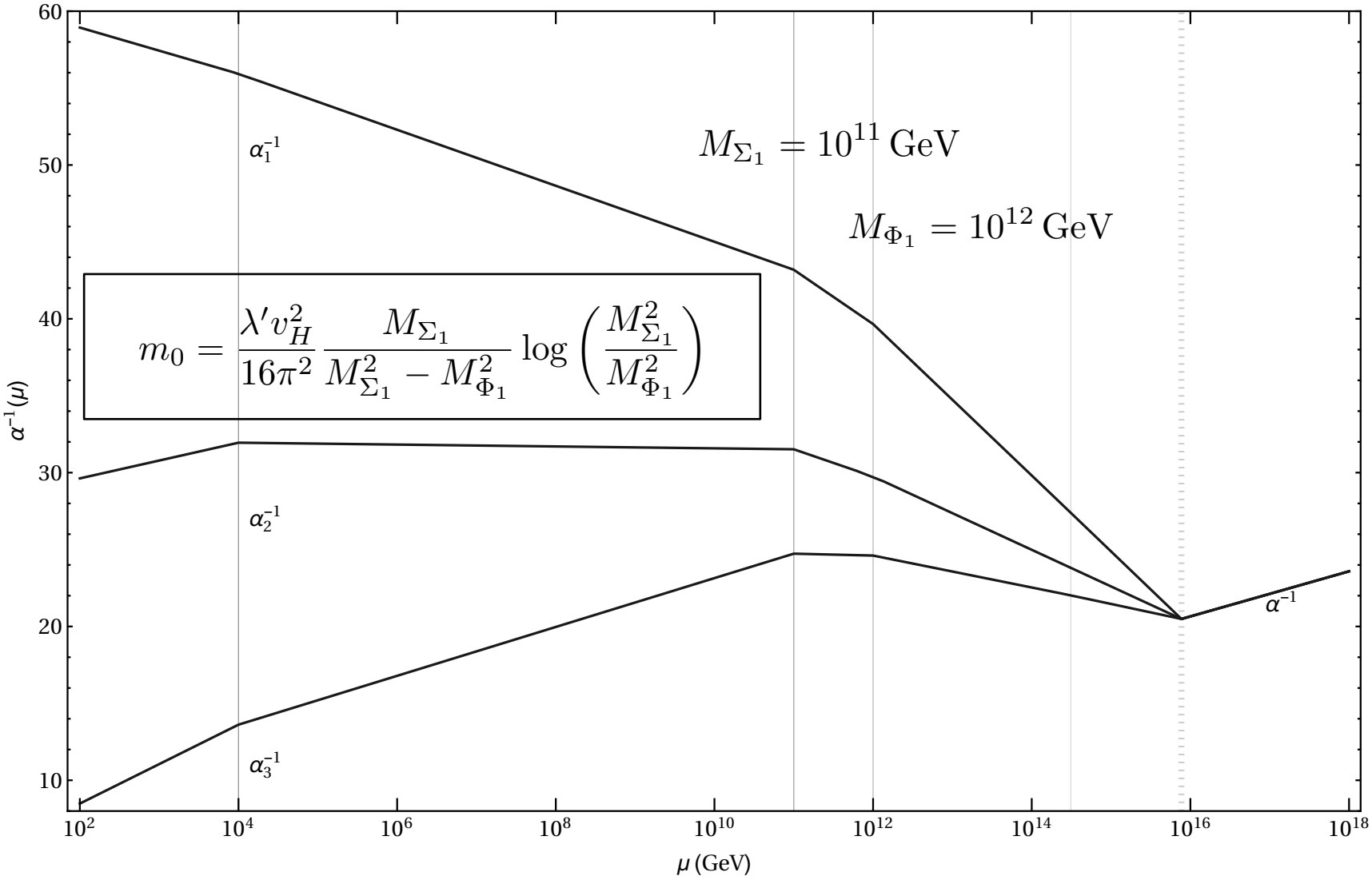
$$\widetilde{Y}^c = \begin{pmatrix} Y_1^c Y_1^{c*} & Y_1^c Y_2^{c*} & Y_1^c Y_3^{c*} \\ Y_2^c Y_1^{c*} & Y_2^c Y_2^{c*} & Y_2^c Y_3^{c*} \\ Y_3^c Y_1^{c*} & Y_3^c Y_2^{c*} & Y_3^c Y_3^{c*} \end{pmatrix} \qquad \widetilde{Y}^{ca} = \begin{pmatrix} Y_1^c Y_1^a & Y_1^c Y_2^a & Y_1^c Y_3^a \\ Y_2^c Y_1^a & Y_2^c Y_2^a & Y_2^c Y_3^a \\ Y_3^c Y_1^a & Y_3^c Y_2^a & Y_3^c Y_3^a \end{pmatrix}$$

$$M_u = \left(\mathbb{I} + \frac{5}{48} \frac{V_{GUT}^2}{M_{\Sigma_3}^2} \widetilde{Y}^c \right)^{-\frac{1}{2}} \frac{1}{\sqrt{2}} v_5 Y^u$$

$$M_d = \left(\mathbb{I} + \frac{5}{48} \frac{V_{GUT}^2}{M_{\Sigma_3}^2} \widetilde{Y}^c \right)^{-\frac{1}{2}} \left(\frac{1}{\sqrt{2}} v_5^* Y^d + \frac{1}{4} \sqrt{\frac{5}{3}} \frac{1}{\sqrt{2}} \frac{v_5^* V_{GUT}}{M_{\Sigma_3}} \widetilde{Y}^{ca} \right)$$

$$M_e = \frac{1}{\sqrt{2}} v_5^* Y^{dT}$$

FITS & PREDICTIONS



FITS & PREDICTIONS

$$M_u = \left(\mathbb{I} + \frac{5}{48}\frac{V_{GUT}^2}{M_{\Sigma_3}^2}\widetilde{Y}^c\right)^{-\frac{1}{2}} \frac{1}{\sqrt{2}} v_5 Y^u$$

$$M_d = \left(\mathbb{I} + \frac{5}{48}\frac{V_{GUT}^2}{M_{\Sigma_3}^2}\widetilde{Y}^c\right)^{-\frac{1}{2}} \left(\frac{1}{\sqrt{2}} v_5^* Y^d + \frac{1}{4}\sqrt{\frac{5}{3}}\frac{1}{\sqrt{2}}\frac{v_5^* V_{GUT}}{M_{\Sigma_3}}\widetilde{Y}^{ca}\right)$$

$$M_e = \frac{1}{\sqrt{2}} v_5^* Y^{dT}$$

$$\mathcal{M}_{ij}^{\nu} \sim m_0 \begin{pmatrix} 2Y_1^a Y_1^b & Y_2^a Y_1^b + Y_1^a Y_2^b & Y_3^a Y_1^b + Y_1^a Y_3^b \\ Y_2^a Y_1^b + Y_1^a Y_2^b & 2Y_2^a Y_2^b & Y_3^a Y_2^b + Y_2^a Y_3^b \\ Y_3^a Y_1^b + Y_1^a Y_3^b & Y_3^a Y_2^b + Y_2^a Y_3^b & 2Y_3^a Y_3^b \end{pmatrix}$$

$$\widetilde{Y}^{ca} = \begin{pmatrix} Y_1^c Y_1^a & Y_1^c Y_2^a & Y_1^c Y_3^a \\ Y_2^c Y_1^a & Y_2^c Y_2^a & Y_2^c Y_3^a \\ Y_3^c Y_1^a & Y_3^c Y_2^a & Y_3^c Y_3^a \end{pmatrix}$$

FITS & PREDICTIONS

$$m_0 = 9.28134365 \times 10^{-12}\,\mathrm{GeV}$$

$$\{Y_1^a, Y_2^a, Y_3^a\} = \{-0.08996953, 0.55129976, 1\}$$

$$\{Y_1^b, Y_2^b, Y_3^b\} = \{0.97595416, 2.38104322, 1\}$$

$$\widetilde{Y}^{ca} = \begin{pmatrix} Y_1^c Y_1^a & Y_1^c Y_2^a & Y_1^c Y_3^a \\ Y_2^c Y_1^a & Y_2^c Y_2^a & Y_2^c Y_3^a \\ Y_3^c Y_1^a & Y_3^c Y_2^a & Y_3^c Y_3^a \end{pmatrix}$$

$$M_u = \left(\mathbb{I} + \frac{5}{48}\frac{V_{GUT}^2}{M_{\Sigma_3}^2}\widetilde{Y}^c\right)^{-\frac{1}{2}} \frac{1}{\sqrt{2}} v_5 Y^u$$

$$M_d = \left(\mathbb{I} + \frac{5}{48}\frac{V_{GUT}^2}{M_{\Sigma_3}^2}\widetilde{Y}^c\right)^{-\frac{1}{2}} \left(\frac{1}{\sqrt{2}} v_5^* Y^d + \frac{1}{4}\sqrt{\frac{5}{3}}\frac{1}{\sqrt{2}}\frac{v_5^* V_{GUT}}{M_{\Sigma_3}}\widetilde{Y}^{ca}\right)$$

$$M_e = \frac{1}{\sqrt{2}} v_5^* Y^{dT}$$

FITS & PREDICTIONS

$$m_0 = 9.28134365 \times 10^{-12}\,\mathrm{GeV}$$

$$\{Y_1^a, Y_2^a, Y_3^a\} = \{-0.08996953, 0.55129976, 1\}$$

$$\{Y_1^b, Y_2^b, Y_3^b\} = \{0.97595416, 2.38104322, 1\}$$

$$\{Y_1^c, Y_2^c, Y_3^c\} = -1.86588 \times 10^{-7}\{0.001370245, 0.0942267033, 1\}$$

CONCLUSIONS

$$5_H,\ 24_H,\ 35_H,\ \overline{5}_{Fi},\ 10_{Fi},\ 15_F,\ \overline{15}_F, \qquad i = 1, 2, 3$$

$$Y_i^a,\ Y_i^b,\ Y_i^c,\ Y_{ij}^u,\ Y_{ij}^d, \qquad i, j = 1, 2, 3$$

THANK YOU

dorsner@fesb.hr