LEPTOQUARK MASS LIMIT IN *SU*(5)*

Ilja Doršner

University of Sarajevo, Bosnia and Herzegovina

Probing the Standard Model and New Physics at Low and High Energies

Portorož, Slovenia

April 15, 2013

* I. Doršner, *Phys. Rev.* D 86:055009, 2012, 1206.5998;
I. Doršner, S. Fajfer and N. Košnik, *Phys. Rev.* D 86:015013, 2012, 1204.0674.

OUTLINE

•MINIMAL UNIFICATION OF MATTER

THE GEORGI-GLASHOW *SU*(5) SCENARIO

• $d = 6$ **PROTON DECAY OPERATORS**

SCALAR CONTRIBUTIONS

•MINIMAL VIABLE *SU*(5) UNIFICATION

•*p*-DECAY PREDICTIONS

THE MINIMAL VIABLE SU*(5)* SCENARIO

NOTATION
(FIELDS)

FIELD ≡ ($SU(\mathbf{3})$, $SU(\mathbf{2})$, $U(1)$)

$$e_a^C \equiv (\mathbf{1}, \mathbf{1}, 1)_a$$

$$Q = I_3 + Y$$

$Q \equiv$ ELECTRIC CHARGE

$I_3 \equiv$ $SU(2)$ ISOSPIN

$Y \equiv$ $U(1)$ HYPERCHARGE

$a = 1, 2, 3$
FAMILY INDEX

$SU(5)$ SCENARIO*

FERMIONS OF THE STANDARD MODEL:

$$L_a \equiv (\mathbf{1}, \mathbf{2}, -1/2)_a = (\nu_a \quad e_a)^T$$

$$e_a^C \equiv (\mathbf{1}, \mathbf{1}, 1)_a$$

LEPTONS

$$Q_a \equiv (\mathbf{3}, \mathbf{2}, 1/6)_a = (u_a \quad d_a)^T$$

$$u_a^C \equiv (\overline{\mathbf{3}}, \mathbf{1}, -2/3)_a$$

$$d_a^C \equiv (\overline{\mathbf{3}}, \mathbf{1}, 1/3)_a$$

QUARKS

*H. Georgi and S.L. Glashow (1974).

$SU(5)$ SCENARIO[*]

FERMIONS OF THE STANDARD MODEL:

$$L_a \equiv (\mathbf{1}, \mathbf{2}, -1/2)_a = (\nu_a \quad e_a)^T$$

$$e_a^C \equiv (\mathbf{1}, \mathbf{1}, 1)_a$$

LEPTONS

$$Q_a \equiv (\mathbf{3}, \mathbf{2}, 1/6)_a = (u_a \quad d_a)^T$$

$$u_a^C \equiv (\overline{\mathbf{3}}, \mathbf{1}, -2/3)_a$$

QUARKS

$$d_a^C \equiv (\overline{\mathbf{3}}, \mathbf{1}, 1/3)_a$$

$(\overline{\mathbf{5}}_{\alpha})_a$

$a = 1, 2, 3$
FAMILY INDEX

$\alpha, \beta = 1, 2, 3, 4, 5$
GROUP INDICES

[*]H. Georgi and S.L. Glashow (1974).

SU(5) SCENARIO*

FERMIONS OF THE STANDARD MODEL:

LEPTONS

$L_a \equiv (\mathbf{1}, \mathbf{2}, -1/2)_a = (\nu_a \quad e_a)^T$

$e^C_a \equiv (\mathbf{1}, \mathbf{1}, 1)_a$

QUARKS

$Q_a \equiv (\mathbf{3}, \mathbf{2}, 1/6)_a = (u_a \quad d_a)^T$

$u^C_a \equiv (\overline{\mathbf{3}}, \mathbf{1}, -2/3)_a$

$d^C_a \equiv (\overline{\mathbf{3}}, \mathbf{1}, 1/3)_a$

$(\mathbf{10}^{\alpha\beta})_a$: e^C_a, Q_a, u^C_a

$(\overline{\mathbf{5}}_\alpha)_a$: L_a, d^C_a

$a = 1, 2, 3$
FAMILY INDEX

$\alpha, \beta = 1, 2, 3, 4, 5$
GROUP INDICES

*H. Georgi and S.L. Glashow (1974).

FERMION MASSES

(SCALAR REPRESENTATIONS IN THE MINIMAL *SU*(5))

5

$$\epsilon_{\alpha\beta\gamma\delta\epsilon}\ (Y)_{ij}\ (\mathbf{10}^{\alpha\beta})_i(\mathbf{10}^{\gamma\delta})_j\mathbf{5}^{\epsilon}$$

&

$$\langle\mathbf{5}\rangle = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \langle\mathbf{5}^5\rangle \end{pmatrix} \qquad \langle\mathbf{5}^5\rangle = (246\,\mathrm{GeV})$$

$$M_U = 2(Y^T + Y)\langle\mathbf{5}^5\rangle$$

$Y \equiv$ Yukawa coupling(s)

$$U^T M_U U_C = M_U^{\mathrm{diag}}$$

NOTATION
(VACUUM EXPECTATION VALUE)

$\mathbf{5}$

$$\langle \mathbf{5}^5 \rangle = v_5/\sqrt{2}$$

<u>**WHAT GOES WRONG WITH *SU*(5)?***</u>*

*H. Georgi and S.L. Glashow (1974).

FERMION MASSES

$Y^{10}_{ij} \mathbf{10}_i \mathbf{10}_j \mathbf{5}$ ➡ $M_U = \sqrt{2}(Y^{10} + Y^{10\,T}) v_5$

$Y^{\bar{5}}_{ij} \mathbf{10}_i \bar{\mathbf{5}}_j \mathbf{5}^*$ ➡

$$M_D = -\frac{1}{2} Y^{\bar{5}} v_5^*$$

$$M_E = -\frac{1}{2} Y^{\bar{5}\,T} v_5^*$$

FERMION MASSES

$$Y^{10}_{ij}\mathbf{10}_i\mathbf{10}_j\mathbf{5} \Rightarrow M_U = \sqrt{2}(Y^{10} + Y^{10\,T})v_5$$

✓

$$Y^{\bar{5}}_{ij}\mathbf{10}_i\bar{\mathbf{5}}_j\mathbf{5}^* \Rightarrow$$

$$M_D = -\frac{1}{2}Y^{\bar{5}}v_5^*$$

$$M_E = -\frac{1}{2}Y^{\bar{5}\,T}v_5^*$$

☐

FERMION MASSES

$$Y^{10}_{ij}\mathbf{10}_i\mathbf{10}_j\mathbf{5} \quad \Rightarrow \quad M_U = \sqrt{2}(Y^{10} + Y^{10\,T})v_5$$

✓

$$Y^{\bar{5}}_{ij}\mathbf{10}_i\bar{\mathbf{5}}_j\mathbf{5}^* \quad \Rightarrow \quad M_D = -\frac{1}{2}Y^{\bar{5}}v_5^*$$

$$M_E = -\frac{1}{2}Y^{\bar{5}\,T}v_5^*$$

☒

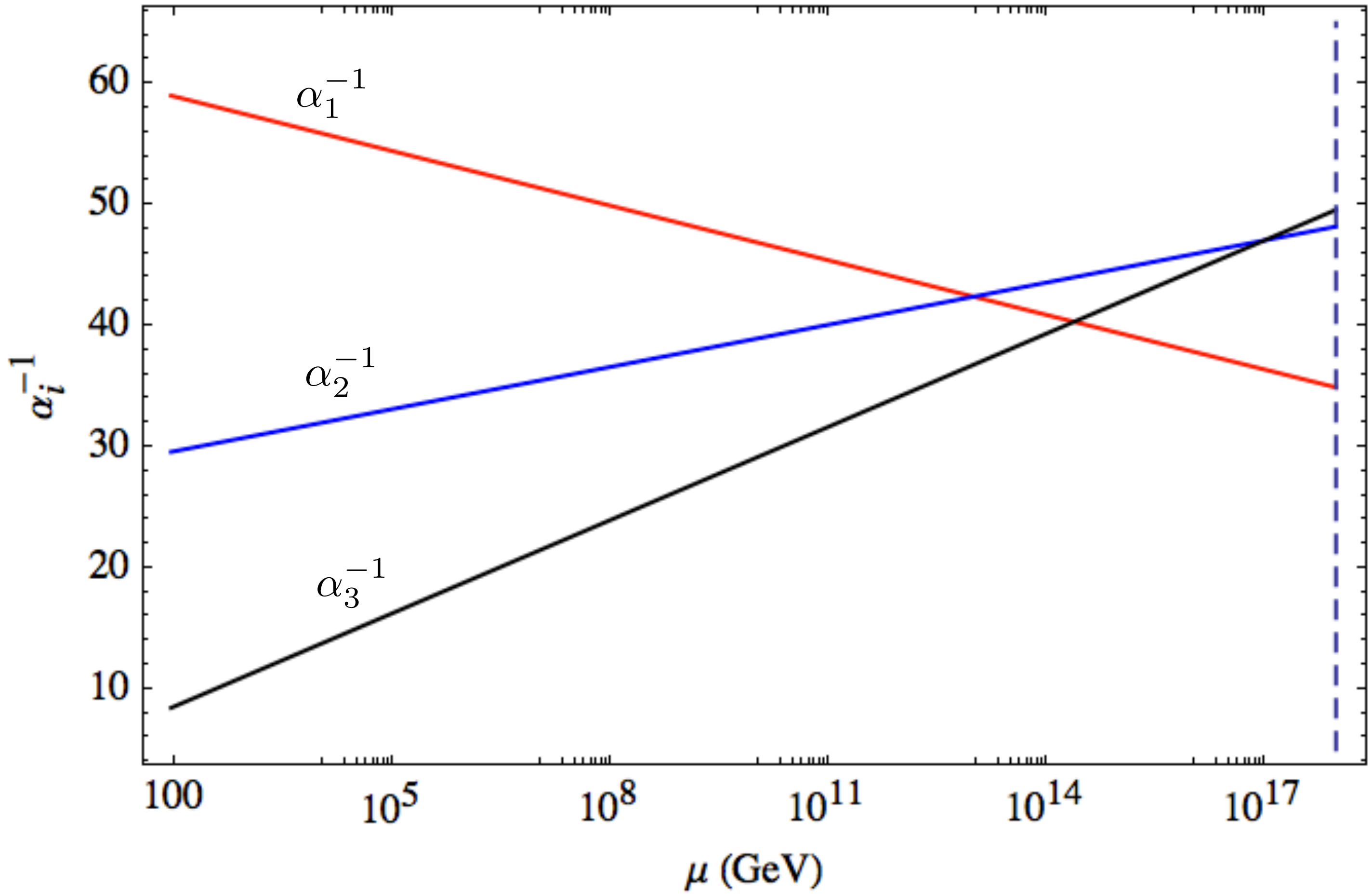
NOTATION

(MASS MATRICES AND UNITARY TRANSFORMATIONS)

DIRAC FERMIONS: UP-, DOWN-QUARKS AND CHARGED LEPTONS

$$U^T M_U U_C = M_U^{\text{diag}} \qquad D^T M_D D_C = M_D^{\text{diag}} \qquad E^T M_E E_C = M_E^{\text{diag}}$$

IS UNIFICATION WRONG WITHIN *SU(5)*?*



*H. Georgi and S.L. Glashow (1974).

NEUTRINO MASSES WITHIN $SU(5)$?*

15¶	**24**‡

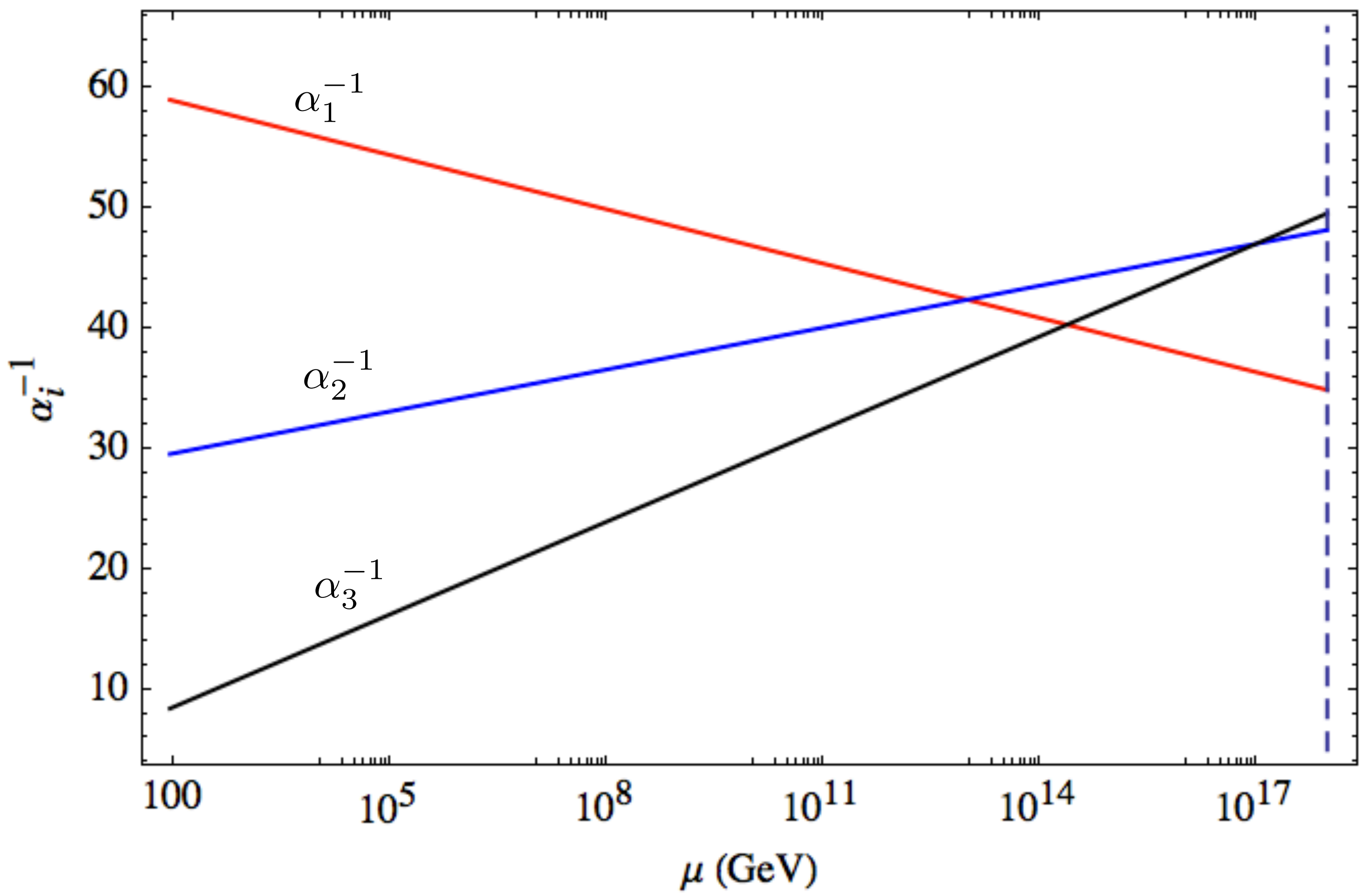
ADDRESSING NEUTRINO MASSES ALSO ADDRESSES UNIFICATION IN A SATISFACTORY MANNER!

¶I. Doršner and P. Fileviez Pérez, *Nucl. Phys.* B 723:53-76, 2005, hep-ph/0504276.

‡B. Bajc and G. Senjanović, *JHEP* 0708 014, 2007, hep-ph/0612029.

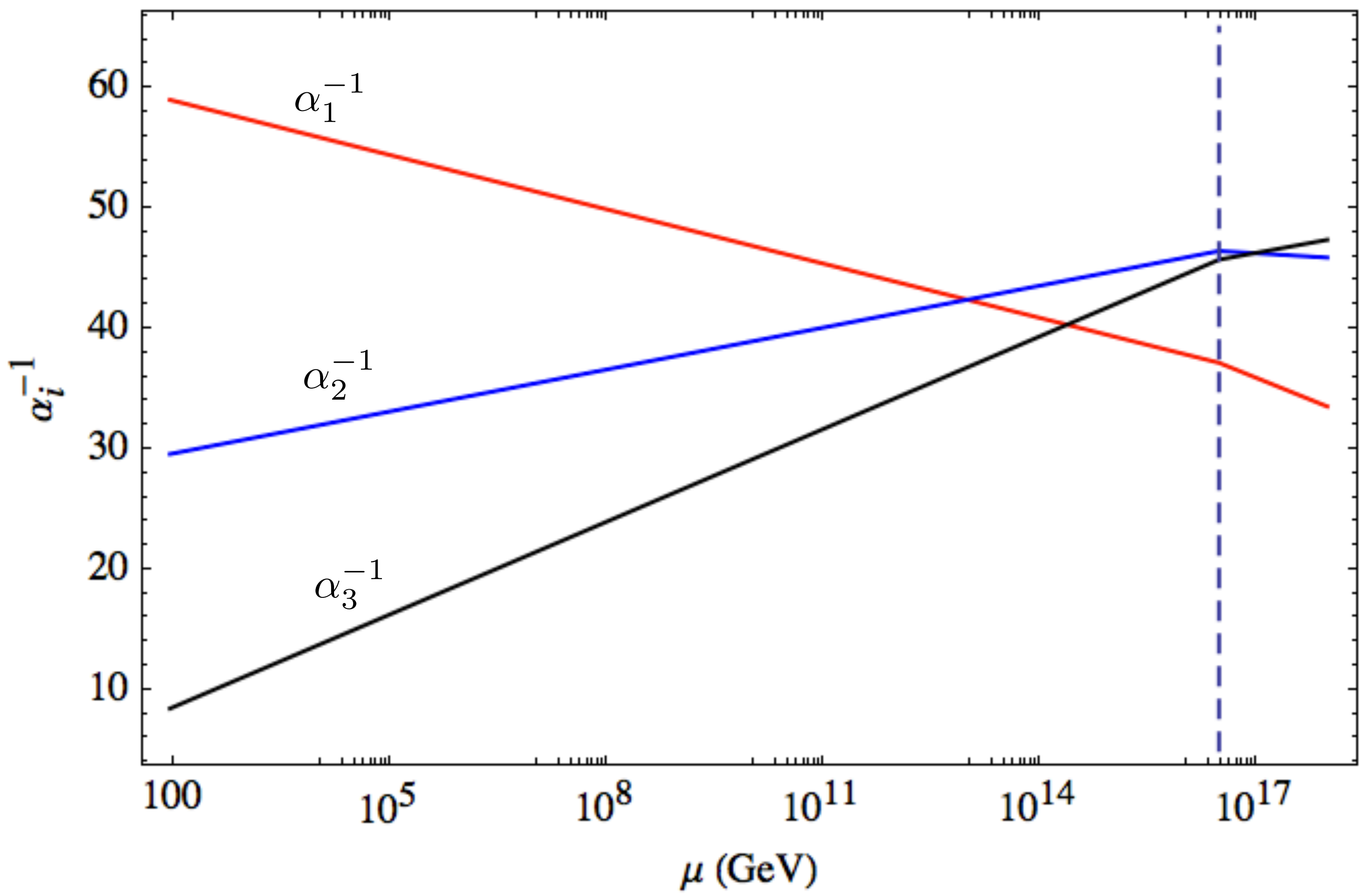
*H. Georgi and S.L. Glashow (1974).

UNIFICATION IN *SU*(5)*



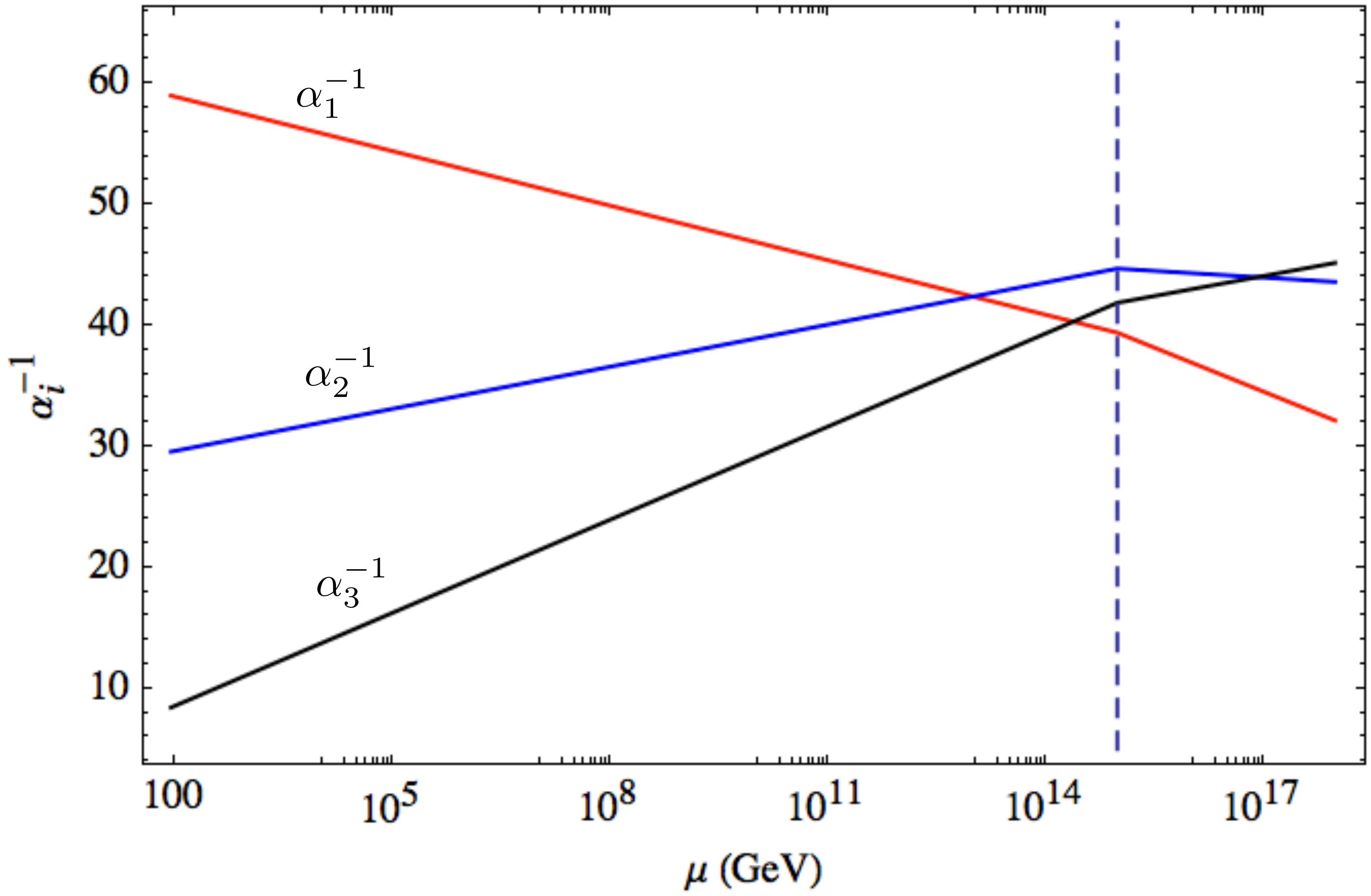
*H. Georgi and S.L. Glashow (1974).

UNIFICATION IN *SU*(5)*



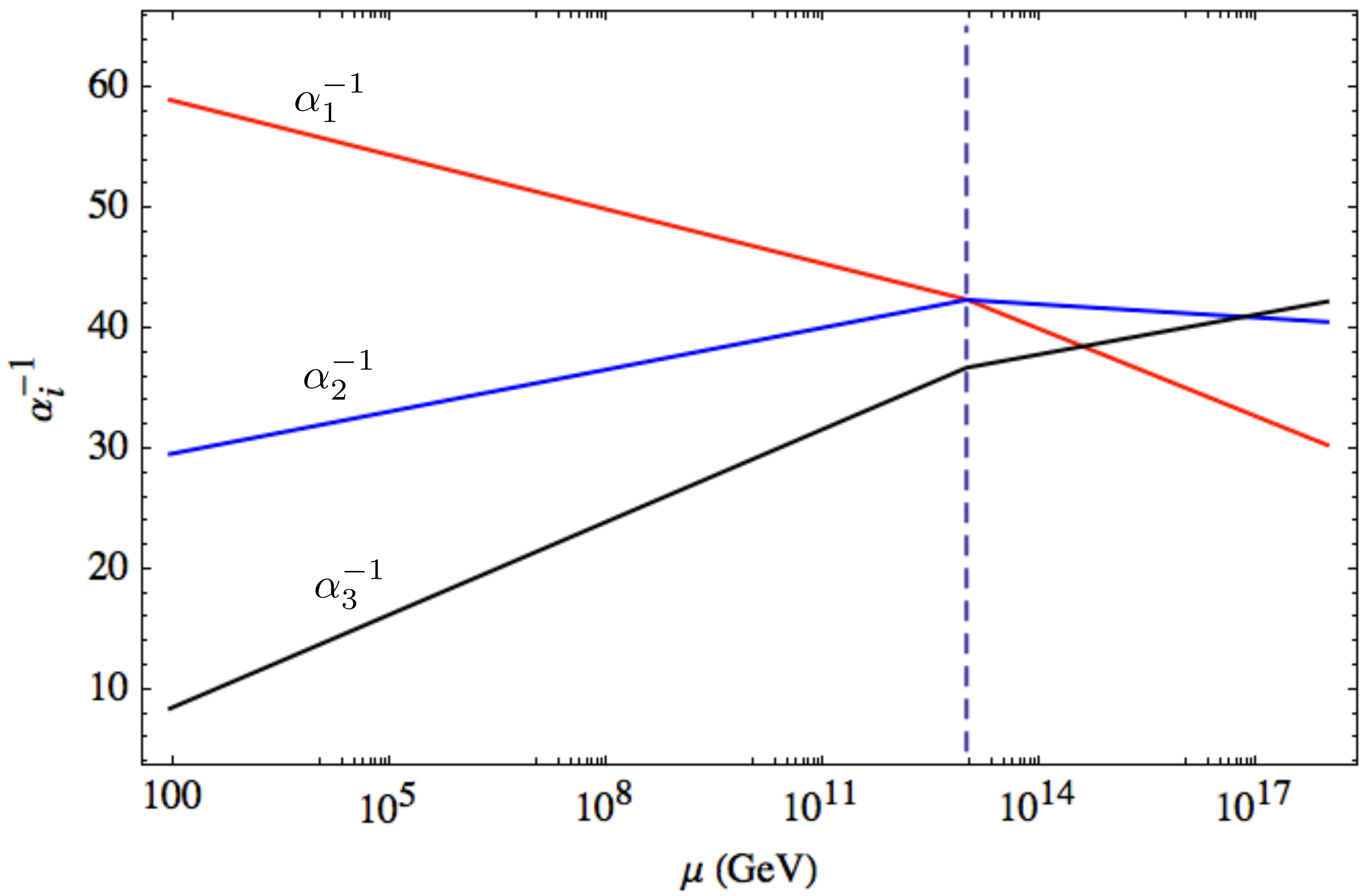
*H. Georgi and S.L. Glashow (1974).

UNIFICATION IN *SU*(5)*



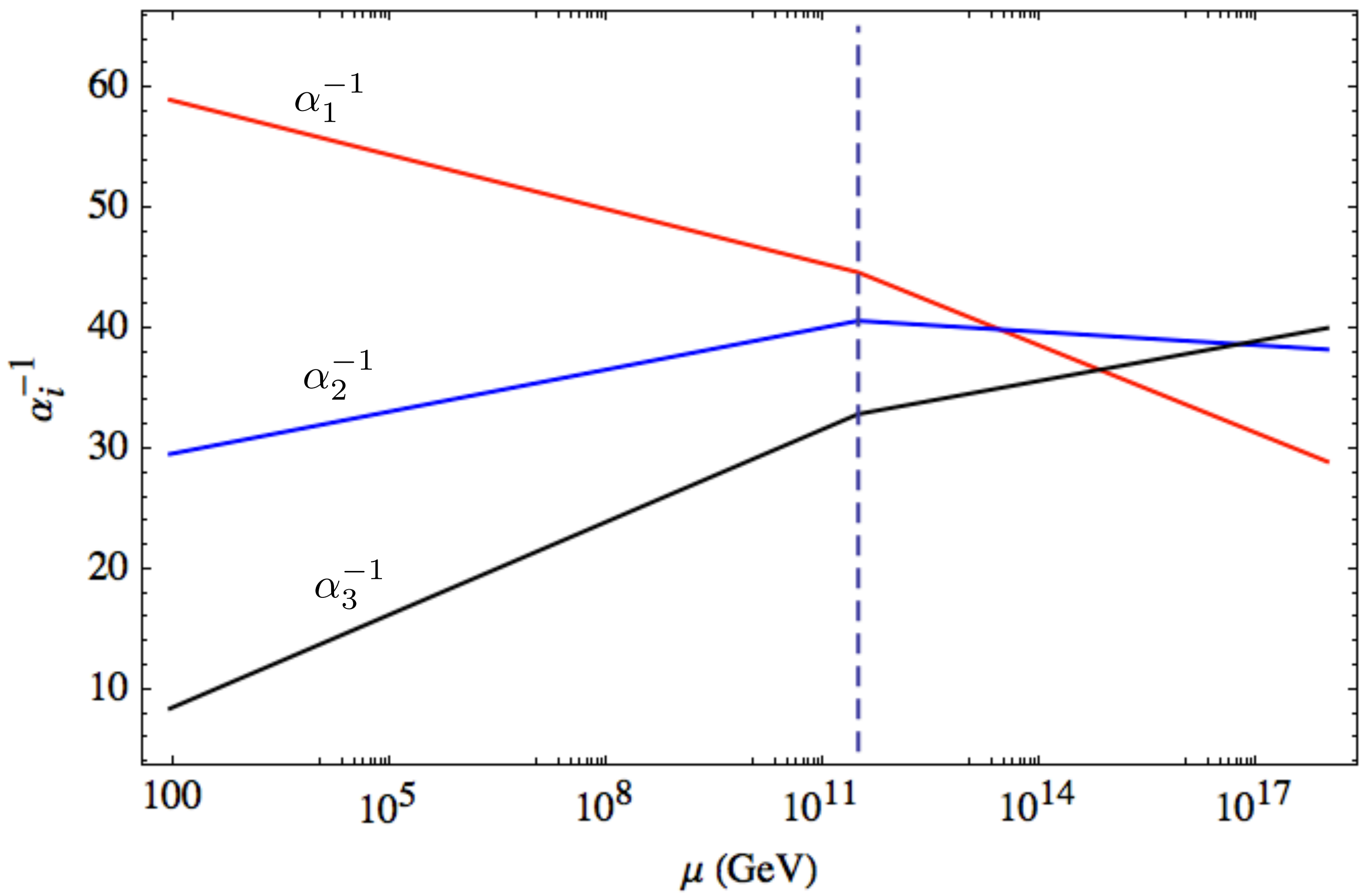
*H. Georgi and S.L. Glashow (1974).

UNIFICATION IN *SU*(5)*



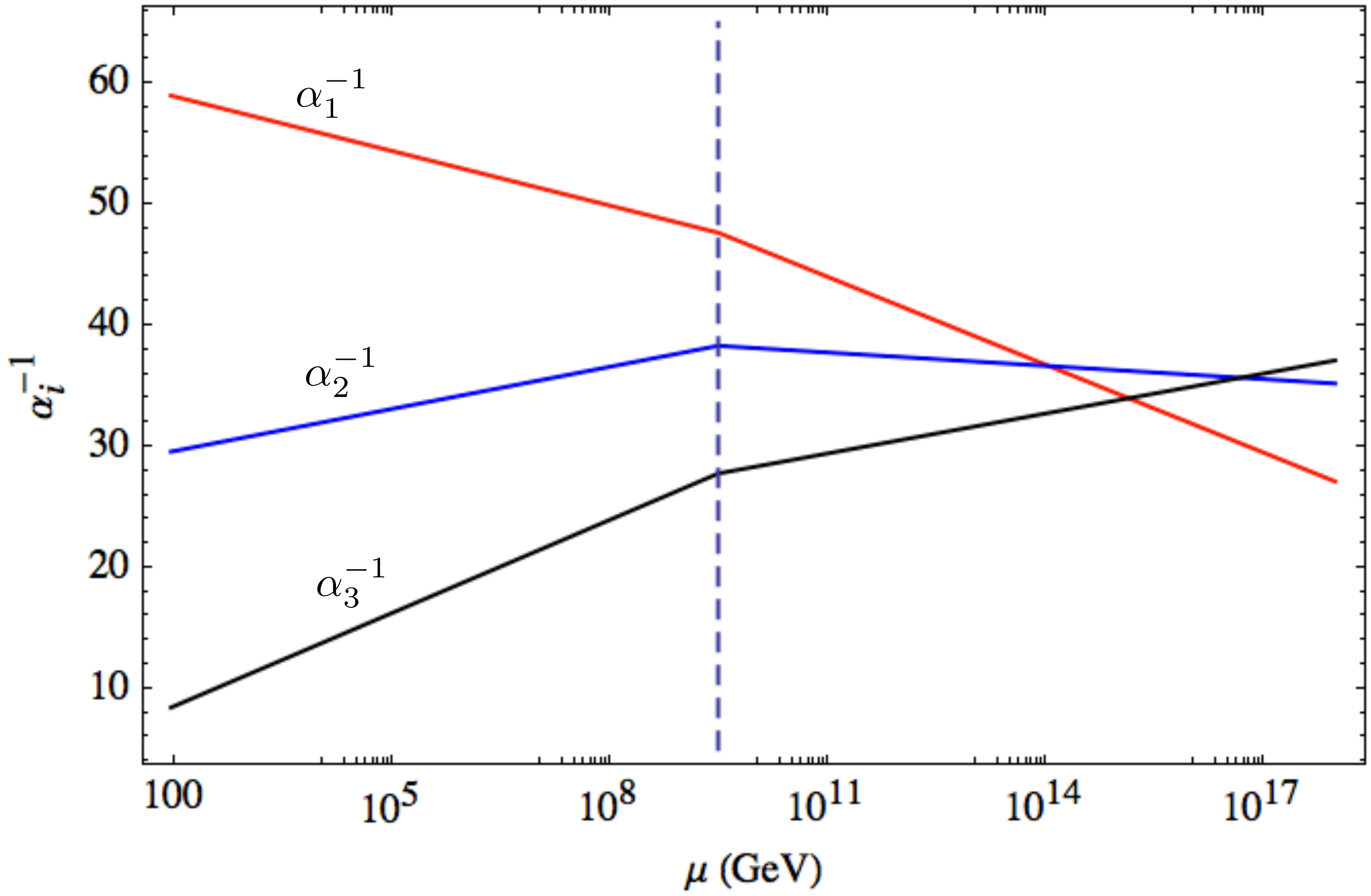
*H. Georgi and S.L. Glashow (1974).

UNIFICATION IN *SU*(5)*



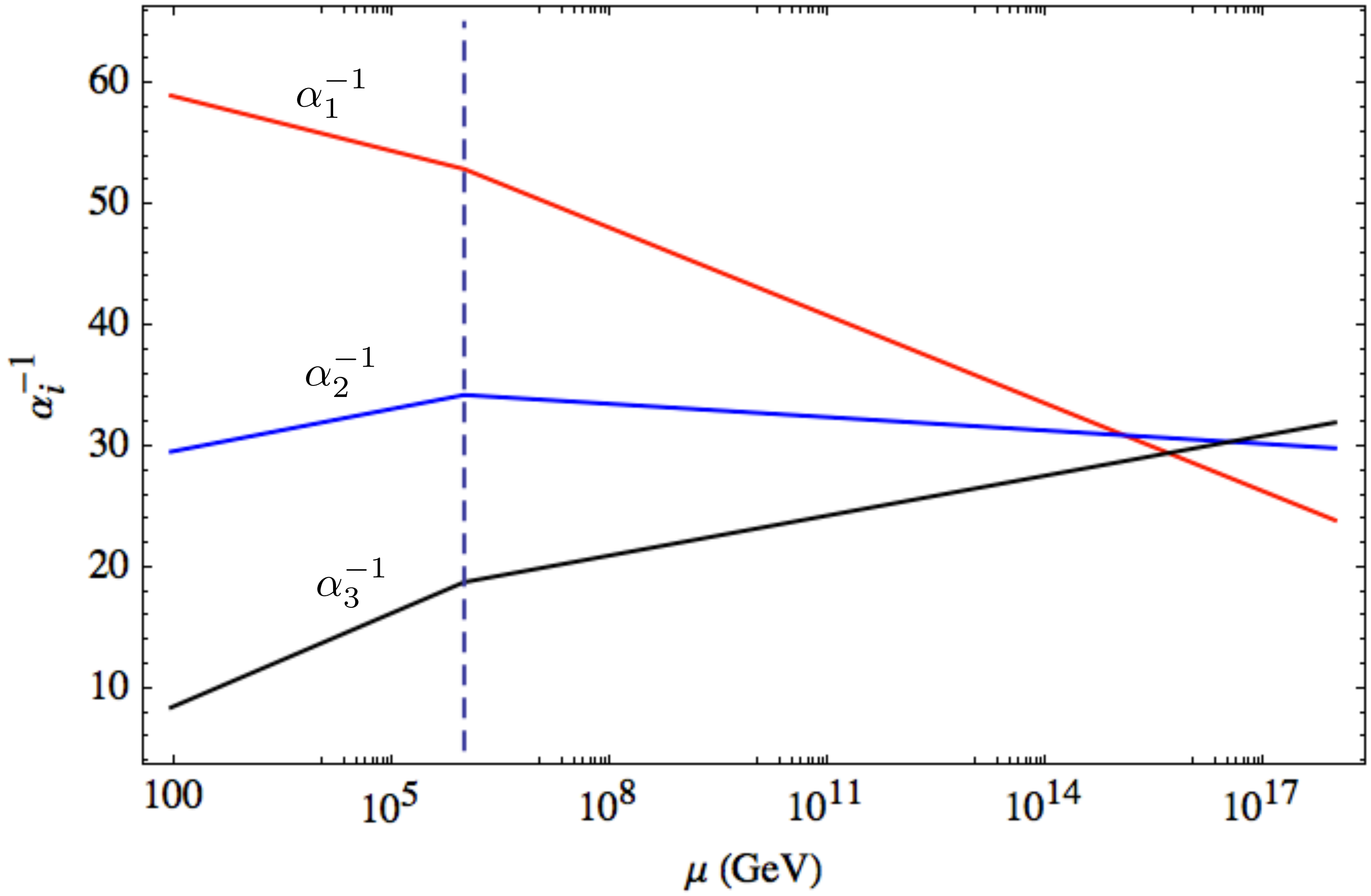
*H. Georgi and S.L. Glashow (1974).

UNIFICATION IN $SU(5)^*$



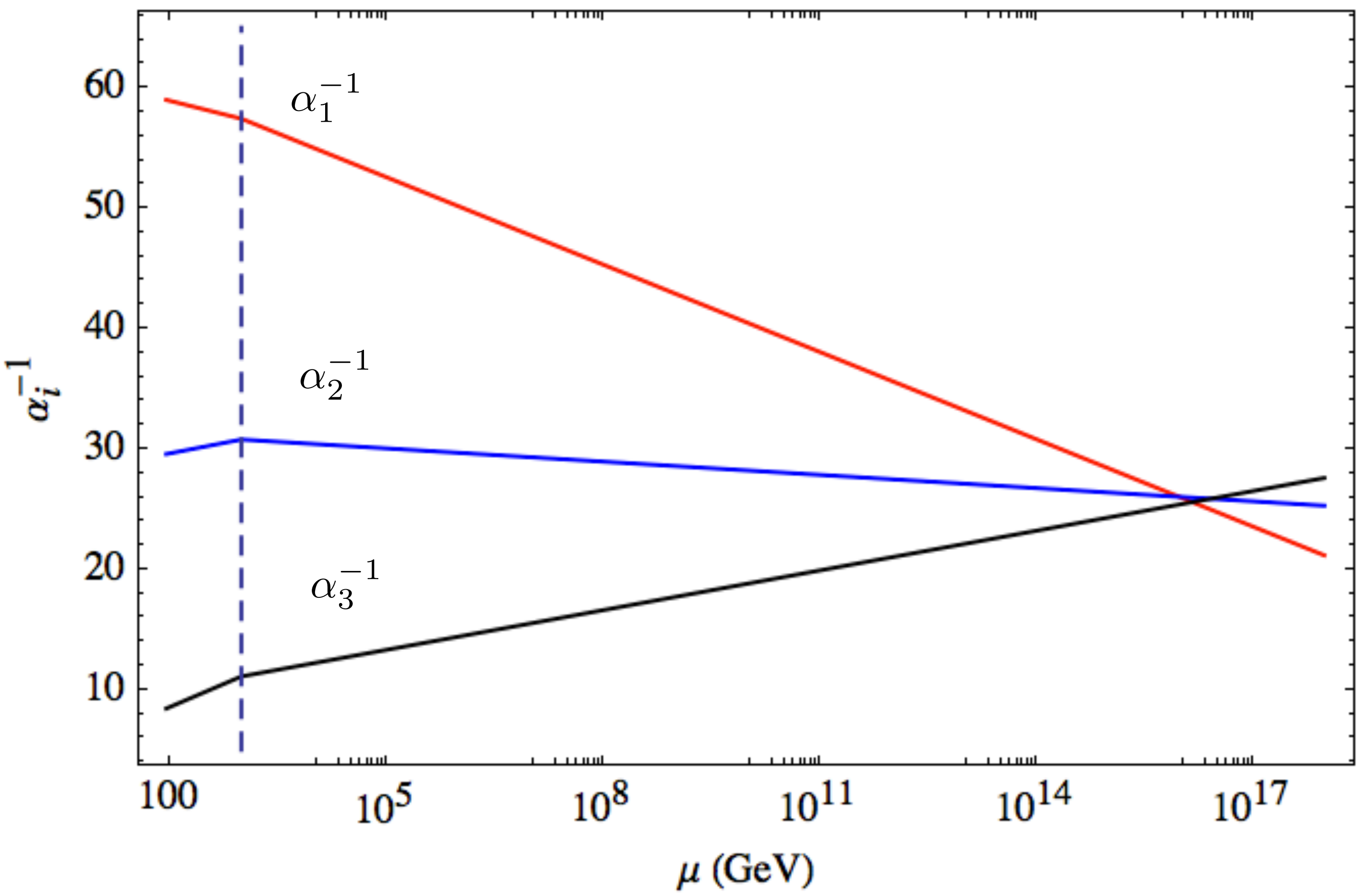
*H. Georgi and S.L. Glashow (1974).

UNIFICATION IN *SU*(5)*



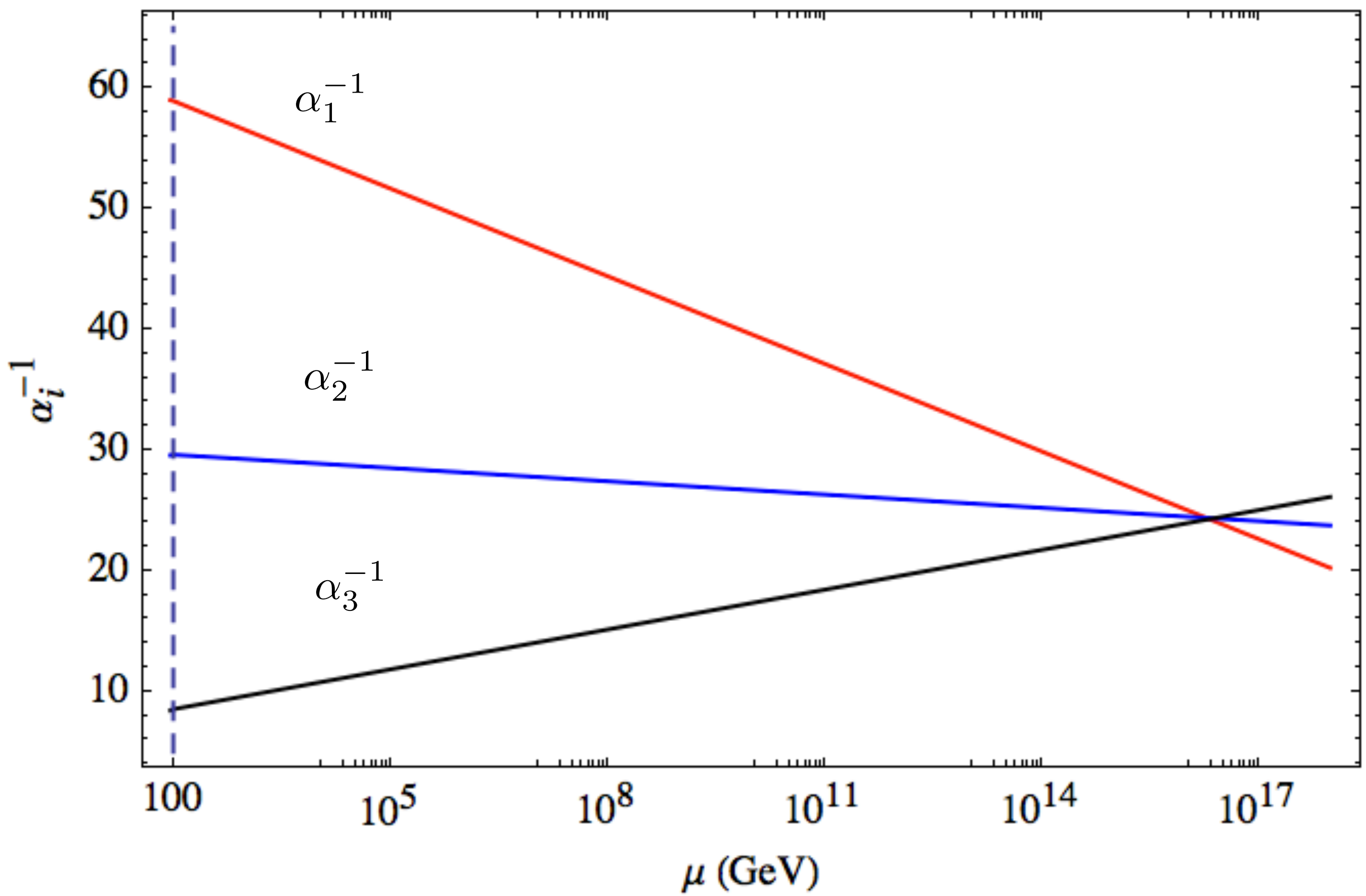
*H. Georgi and S.L. Glashow (1974).

UNIFICATION IN *SU*(5)*



*H. Georgi and S.L. Glashow (1974).

UNIFICATION IN *SU*(5)*



*H. Georgi and S.L. Glashow (1974).

NOTATION

(MASS MATRICES AND UNITARY TRANSFORMATIONS)

MAJORANA FERMIONS: NEUTRINOS

$$N^T \; M_N \; N = M_N^{\rm diag}$$

NOTE: $M_N = M_N^T$

QUALITATIVE ASPECTS OF NEUTRINO PHYSICS ARE NOT RELEVANT FOR DISCUSSION OF *p*-DECAY!

HOW PREDICTIVE IS *SU*(5) FOR *p*-DECAY?*

*H. Georgi and S.L. Glashow (1974).

$d = 6$ PROTON DECAY OPERATORS

$$\dim(\mathcal{L}) = 4$$

$$\dim(\mathcal{O}^d) = d$$

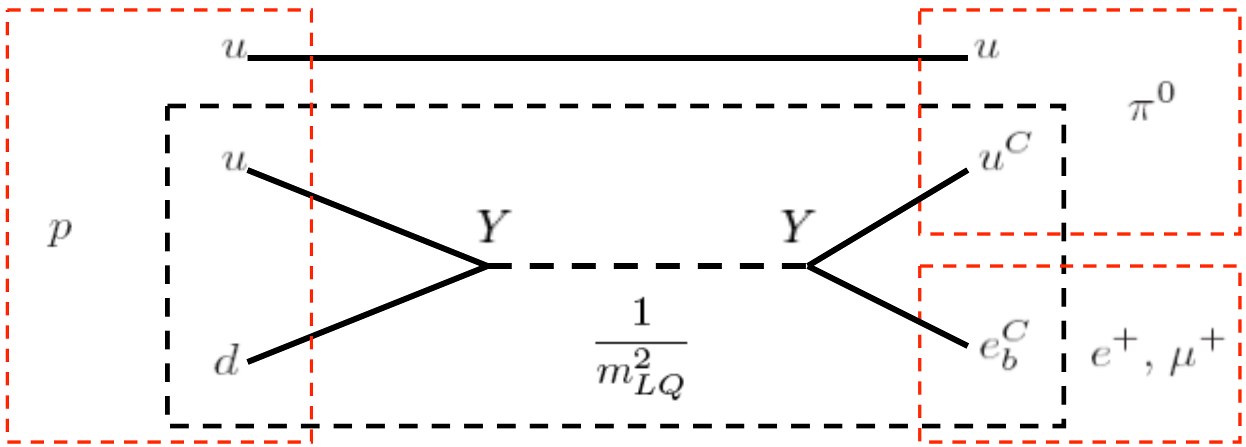
$$\mathcal{L} = c_d \frac{\mathcal{O}^d}{M^{d-4}} = a_d \, \mathcal{O}^d = O_H$$

$$\dim(c_d) = 0$$

$$\dim(a_d) = 4 - d$$

p-DECAY WIDTHS
(SCALAR CONTRIBUTIONS*)

$$\Gamma_6 \sim \frac{Y^4}{m_{LQ}^4} m_p^5$$

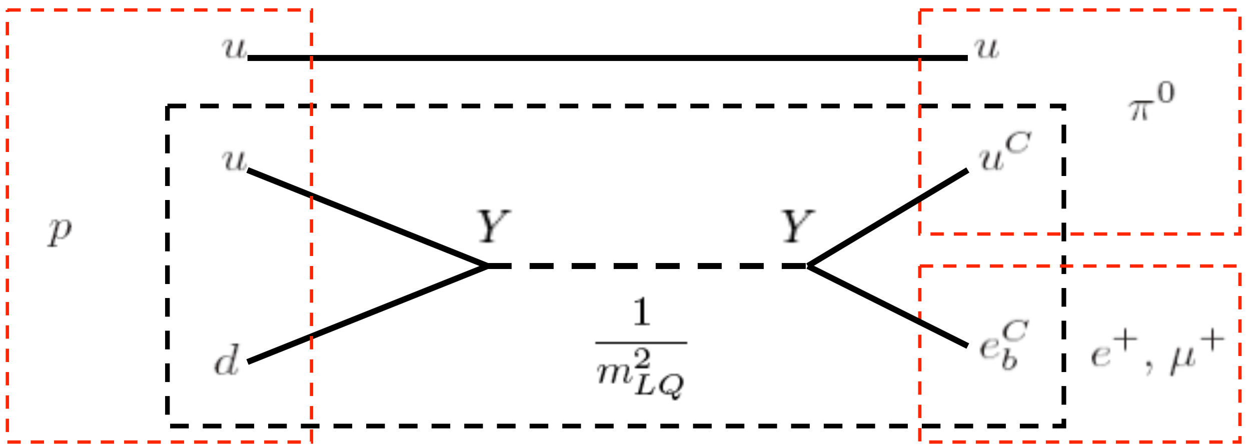


Y ≡ Yukawa coupling(s) m_{LQ} ≡ Leptoquark mass

*S. Weinberg, *Phys. Rev.* D 22:1694, 1980.

p-DECAY WIDTHS
(SCALAR CONTRIBUTIONS*)

$$\Gamma_6 \sim \frac{Y^4}{m_{LQ}^4} m_p^5 \qquad a_6 \sim \frac{Y^2}{m_{LQ}^2}$$



Y ≡ Yukawa coupling(s) m_{LQ} ≡ Leptoquark mass

*S. Weinberg, *Phys. Rev.* D 22:1694, 1980.

EXPERIMENTAL INPUT

(PROTON DECAY)

PROCESS	τ_p $(10^{33}$ years)
$p \to \pi^0 e^+$	8.2
$p \to \pi^0 \mu^+$	6.6
$p \to K^+ \bar{\nu}$	2.3
$p \to K^0 e^+$	1.0
$p \to K^0 \mu^+$	1.3
$p \to \pi^+ \bar{\nu}$	0.025
$\vdots$	$\vdots$
$p \to \pi^0 e^+$	13.0
$p \to \pi^0 \mu^+$	11.0
$p \to K^+ \bar{\nu}$	4.0
$p \to \eta e^+$	4.2
$p \to \eta \mu^+$	1.3
$p \to K^0 \mu^+$	1.6

* (rows $p \to \pi^0 e^+$, $p \to \pi^0 \mu^+$: 8.2, 6.6)
@ (rows $p \to K^+ \bar{\nu}$, $p \to K^0 e^+$, $p \to K^0 \mu^+$: 2.3, 1.0, 1.3)
¶ (rows 13.0, 11.0, 4.0)

*[Super-Kamiokande Collaboration], arXiv:0903.0676.

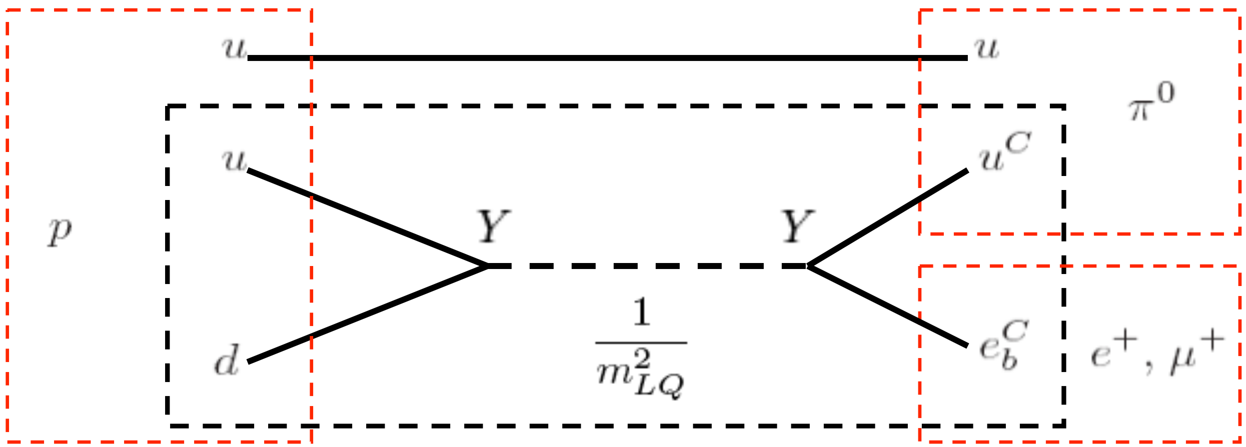
@[Super-Kamiokande Collaboration], arXiv:hep-ex/0502026.

¶http://www.phys.utk.edu/blv2011/sessions01-06.html (Makoto Miura)

#[Super-Kamiokande Collaboration], arXiv:1205.6538.

p-DECAY WIDTHS
(SCALAR CONTRIBUTIONS*)

$$\Gamma_6 \sim \frac{Y^4}{m_{LQ}^4} m_p^5 \quad \Rightarrow \quad m_{LQ} > 10^{12}\,\text{GeV}$$



Y ≡ Yukawa coupling(s) $\qquad$ m_{LQ} ≡ Leptoquark mass

*S. Weinberg, *Phys. Rev.* D 22:1694, 1980.

KEY QUESTION

IS $m_{LQ} > 10^{12}\,\mathrm{GeV}$ AN ACCURATE LIMIT?

LEPTOQUARK IN *SU*(5)

(p-DECAY MEDIATING SCALAR LEPTOQUARK)

$$\mathbf{5} = \begin{pmatrix} \Delta \\ \\ H \end{pmatrix}$$

THERE IS ONLY ONE SET OF PROTON DECAY MEDIATING SCALARS IN THE MINIMAL *SU*(5) SETUP!

<u>LEPTOQUARK IN *SU*(5)</u>

(p-DECAY MEDIATING SCALAR LEPTOQUARK)

$$(\mathbf{3}, \mathbf{1}, -1/3)$$
$$\equiv$$
$$\Delta$$

THERE IS ONLY ONE SET OF PROTON DECAY MEDIATING SCALARS IN THE MINIMAL *SU*(5) SETUP!

$d = 6$ PROTON DECAY OPERATORS

(SCALAR CONTRIBUTIONS)

$$O_H(d_\alpha, e_\beta) \; = \; a(d_\alpha, e_\beta) \; u^T \; L \; C^{-1} \; d_\alpha \; u^T \; L \; C^{-1} e_\beta$$

$$\alpha, \beta (= 1, 2)$$

$d = 6$ PROTON DECAY OPERATORS

(SCALAR CONTRIBUTIONS*)

$$O_H(d_\alpha, e_\beta) = a(d_\alpha, e_\beta)\, u^T\, L\, C^{-1}\, d_\alpha\, u^T\, L\, C^{-1} e_\beta$$

$$O_H(d_\alpha, e^C_\beta) = a(d_\alpha, e^C_\beta)\, u^T\, L\, C^{-1}\, d_\alpha\, e^{C\dagger}_\beta\, L\, C^{-1} u^{C*}$$

$$O_H(d^C_\alpha, e_\beta) = a(d^C_\alpha, e_\beta)\, d^{C\dagger}_\alpha\, L\, C^{-1}\, u^{C*}\, u^T\, L\, C^{-1} e_\beta$$

$$O_H(d^C_\alpha, e^C_\beta) = a(d^C_\alpha, e^C_\beta)\, d^{C\dagger}_\alpha\, L\, C^{-1}\, u^{C*}\, e^{C\dagger}_\beta\, L\, C^{-1} u^{C*}$$

$$O_H(d_\alpha, d_\beta, \nu_i) = a(d_\alpha, d_\beta, \nu_i)\, u^T\, L\, C^{-1}\, d_\alpha\, d^T_\beta\, L\, C^{-1}\, \nu_i$$

$$O_H(d_\alpha, d^C_\beta, \nu_i) = a(d_\alpha, d^C_\beta, \nu_i)\, d^{C\dagger}_\beta\, L\, C^{-1}\, u^{C*}\, d^T_\alpha\, L\, C^{-1}\, \nu_i$$

AGAIN, WE WILL *ASSUME* NEUTRINOS TO BE MAJORANA PARTICLES IN WHAT FOLLOWS.

*P. Nath and P.F. Pérez, *Phys. Rept.* 441 (2007) 191-317.

$d = 6$ PROTON DECAY OPERATORS

(SCALAR CONTRIBUTIONS)

$$
\begin{aligned}
O_H(d_\alpha, e_\beta) &= a(d_\alpha, e_\beta)\, u^T\, L\, C^{-1}\, d_\alpha\, u^T\, L\, C^{-1} e_\beta \\
O_H(d_\alpha, e^C_\beta) &= a(d_\alpha, e^C_\beta)\, u^T\, L\, C^{-1}\, d_\alpha\, e^{C\dagger}_\beta\, L\, C^{-1} u^{C*} \\
O_H(d^C_\alpha, e_\beta) &= a(d^C_\alpha, e_\beta)\, d^{C\dagger}_\alpha\, L\, C^{-1}\, u^{C*}\, u^T\, L\, C^{-1} e_\beta \\
O_H(d^C_\alpha, e^C_\beta) &= a(d^C_\alpha, e^C_\beta)\, d^{C\dagger}_\alpha\, L\, C^{-1}\, u^{C*}\, e^{C\dagger}_\beta\, L\, C^{-1} u^{C*}
\end{aligned}
$$

$$
\begin{aligned}
O_H(d_\alpha, d_\beta, \nu_i) &= a(d_\alpha, d_\beta, \nu_i)\, u^T\, L\, C^{-1}\, d_\alpha\, d^T_\beta\, L\, C^{-1}\, \nu_i \\
O_H(d_\alpha, d^C_\beta, \nu_i) &= a(d_\alpha, d^C_\beta, \nu_i)\, d^{C\dagger}_\beta\, L\, C^{-1}\, u^{C*}\, d^T_\alpha\, L\, C^{-1}\, \nu_i
\end{aligned}
$$

$$i (= 1, 2, 3)$$

$$\alpha + \beta < 4$$

p-DECAY WIDTHS
(SCALAR CONTRIBUTIONS)

$$\Gamma(p \to \bar{\nu}_i \pi^+) = \frac{(m_p^2 - m_{\pi^+}^2)^2}{32\pi f_\pi^2 m_p^3} |\alpha\, a(d_1, d_1^C, \nu_i) + \beta\, a(d_1, d_1, \nu_i)|^2 (1 + D + F)^2$$

$$\tau \sim \Gamma^{-1}$$

$\tau \equiv$ PARTIAL LIFETIME

$d = 6$ PROTON DECAY COEFFICIENTS

(SCALAR CONTRIBUTIONS)

$$\boxed{\begin{array}{c}(\mathbf{3},\mathbf{1},-1/3)\\ \equiv \\ \Delta\end{array}} \quad \in \mathbf{5}$$

$$\begin{aligned}
a(d_\alpha, e_\beta) &= -\frac{\sqrt{2}}{m_\Delta^2}\,(U^T(Y^{10}+Y^{10\,T})D)_{1\alpha}\,(U^T Y^{\bar{5}} E)_{1\beta}\\
a(d_\alpha, e^C_\beta) &= -\frac{4}{m_\Delta^2}\,(U^T(Y^{10}+Y^{10\,T})D)_{1\alpha}\,(E_C^\dagger (Y^{10}+Y^{10\,T})^\dagger U_C^*)_{\beta 1}\\
a(d^C_\alpha, e_\beta) &= \frac{1}{2m_\Delta^2}\,(D_C^\dagger Y^{\bar{5}\,\dagger} U_C^*)_{\alpha 1}\,(U^T Y^{\bar{5}} E)_{1\beta}\\
a(d^C_\alpha, e^C_\beta) &= \frac{\sqrt{2}}{m_\Delta^2}\,(D_C^\dagger Y^{\bar{5}\,\dagger} U_C^*)_{\alpha 1}\,(E_C^\dagger (Y^{10}+Y^{10\,T})^\dagger U_C^*)_{\beta 1}\\
a(d_\alpha, d_\beta, \nu_i) &= \frac{\sqrt{2}}{m_\Delta^2}(U^T(Y^{10}+Y^{10\,T})D)_{1\alpha}\,(D^T Y^{\bar{5}} N)_{\beta i}\\
a(d_\alpha, d^C_\beta, \nu_i) &= -\frac{1}{2m_\Delta^2}\,(D_C^\dagger Y^{\bar{5}\,\dagger} U_C^*)_{\beta 1}\,(D^T Y^{\bar{5}} N)_{\alpha i}
\end{aligned}$$

$d = 6$ PROTON DECAY COEFFICIENTS

(SCALAR CONTRIBUTIONS*)

$$\boxed{\begin{array}{c}(\mathbf{3}, \mathbf{1}, -1/3)\\ \equiv \\ \Delta\end{array}} \quad \in \mathbf{5}$$

$$\begin{aligned}
a(d_\alpha, e_\beta) &= -\frac{\sqrt{2}}{m_\Delta^2}\,(U^T(Y^{10} + Y^{10\,T})D)_{1\alpha}\,(U^T Y^{\bar{5}} E)_{1\beta}\\
a(d_\alpha, e_\beta^C) &= -\frac{4}{m_\Delta^2}\,(U^T(Y^{10} + Y^{10\,T})D)_{1\alpha}\,(E_C^\dagger (Y^{10} + Y^{10\,T})^\dagger U_C^*)_{\beta 1}\\
a(d_\alpha^C, e_\beta) &= \frac{1}{2m_\Delta^2}\,(D_C^\dagger Y^{\bar{5}\,\dagger} U_C^*)_{\alpha 1}\,(U^T Y^{\bar{5}} E)_{1\beta}\\
a(d_\alpha^C, e_\beta^C) &= \frac{\sqrt{2}}{m_\Delta^2}\,(D_C^\dagger Y^{\bar{5}\,\dagger} U_C^*)_{\alpha 1}\,(E_C^\dagger (Y^{10} + Y^{10\,T})^\dagger U_C^*)_{\beta 1}\\
a(d_\alpha, d_\beta, \nu_i) &= \frac{\sqrt{2}}{m_\Delta^2}(U^T(Y^{10} + Y^{10\,T})D)_{1\alpha}\,(D^T Y^{\bar{5}} N)_{\beta i}\\
a(d_\alpha, d_\beta^C, \nu_i) &= -\frac{1}{2m_\Delta^2}\,(D_C^\dagger Y^{\bar{5}\,\dagger} U_C^*)_{\beta 1}\,(D^T Y^{\bar{5}} N)_{\alpha i}
\end{aligned}$$

*R.N. Mohapatra, *Phys. Rev. Lett.* 43, 893 (1979).

$d = 6$ PROTON DECAY COEFFICIENTS

(SCALAR CONTRIBUTIONS*)

$$\boxed{\begin{matrix}(\mathbf{3}, \mathbf{1}, -1/3) \\ \equiv \\ \Delta\end{matrix}} \quad \in \mathbf{5}$$

$$\boxed{\begin{aligned} E &= D_C \\ D &= E_C \\ U &= U_C \end{aligned}} \qquad \boxed{U^\dagger D = V_{CKM}} \qquad \boxed{\begin{aligned} N &= I \\ E &= I \\ D &= I \end{aligned}}$$

*R.N. Mohapatra, *Phys. Rev. Lett.* 43, 893 (1979).

HOW PREDICTIVE IS *SU*(5) FOR *p*-DECAY?*

MINIMAL *SU*(5) IS VERY PREDICTIVE BECAUSE IT IS NOT VIABLE!

*H. Georgi and S.L. Glashow (1974).

MINIMAL VIABLE *SU*(5)

(CHARGED FERMION MASSES)

$$\epsilon_{\alpha\beta\gamma\delta\eta} Y_{ij} \; \mathbf{10}_i^{\alpha\beta} \; \mathbf{10}_j^{\gamma\delta} \; \mathbf{5}^{\eta} \quad \Rightarrow \quad M_U$$

$$Y_{ij} \; \mathbf{10}_i^{\alpha\beta} \; \overline{\mathbf{5}}_{j\beta} \; \mathbf{5}^*_{\alpha}$$

$$Y_{ij} \; \mathbf{10}_i^{\alpha\beta} \; \frac{\mathbf{24}_{\beta}^{\gamma}}{\Lambda} \; \overline{\mathbf{5}}_{j\gamma} \; \mathbf{5}^*_{\alpha}$$

$$\Rightarrow \quad M_D, \quad M_E$$

$\Lambda \equiv$ CUTOFF

PREDICTIONS*

(MINIMAL VIABLE *SU*(5))

$$O_H(d_\alpha, d_\beta, \nu_i) \;=\; a(d_\alpha, d_\beta, \nu_i)\; u^T\; L\; C^{-1}\; d_\alpha\; d_\beta^T\; L\; C^{-1}\; \nu_i$$

$$O_H(d_\alpha, d_\beta^C, \nu_i) \;=\; a(d_\alpha, d_\beta^C, \nu_i)\; d_\beta^{C\,\dagger}\; L\; C^{-1}\; u^{C\,*}\; d_\alpha^T\; L\; C^{-1}\; \nu_i$$

*I. Doršner, S. Fajfer and N. Košnik, *Phys. Rev.* D 86:015013, 2012, 1204.0674.

PREDICTIONS[*]

(MINIMAL VIABLE *SU*(5))

$$a(d_j, d_k, \nu_i) = \frac{2}{m_\Delta^2 v_5^2} (M_U^{\mathrm{diag}} K_0 V_{UD})_{1j} (D^T M_D N)_{ki}$$

$$a(d_j, d_k^C, \nu_i) = -\frac{2}{m_\Delta^2 v_5^2} (V_{UD} M_D^{\mathrm{diag}})_{1k} (D^T M_D N)_{ji}$$

$$U^\dagger D \equiv V_{UD}$$

[*] I. Doršner, *Phys. Rev.* D 86:055009, 2012, 1206.5998.

PREDICTIONS

(MINIMAL VIABLE *SU*(5))

$$M_U = M_U^T$$

$$\sum_{i=1,2,3} (D^T M_D N)_{\alpha i} (D^T M_D N)^*_{\beta i} = (M_D^{\mathrm{diag}\,2})_{\alpha\beta}$$

$$a(d_j, d_k, \nu_i) = \frac{2}{m_\Delta^2 v_5^2} (M_U^{\mathrm{diag}} K_0 V_{UD})_{1j} (D^T M_D N)_{ki}$$

PREDICTIONS

(MINIMAL VIABLE *SU*(5))

$$M_U = M_U^T$$

↓

$$U = U_C K_0$$

↓

$$(K_0)_{11} = e^{i\phi}$$

PREDICTIONS

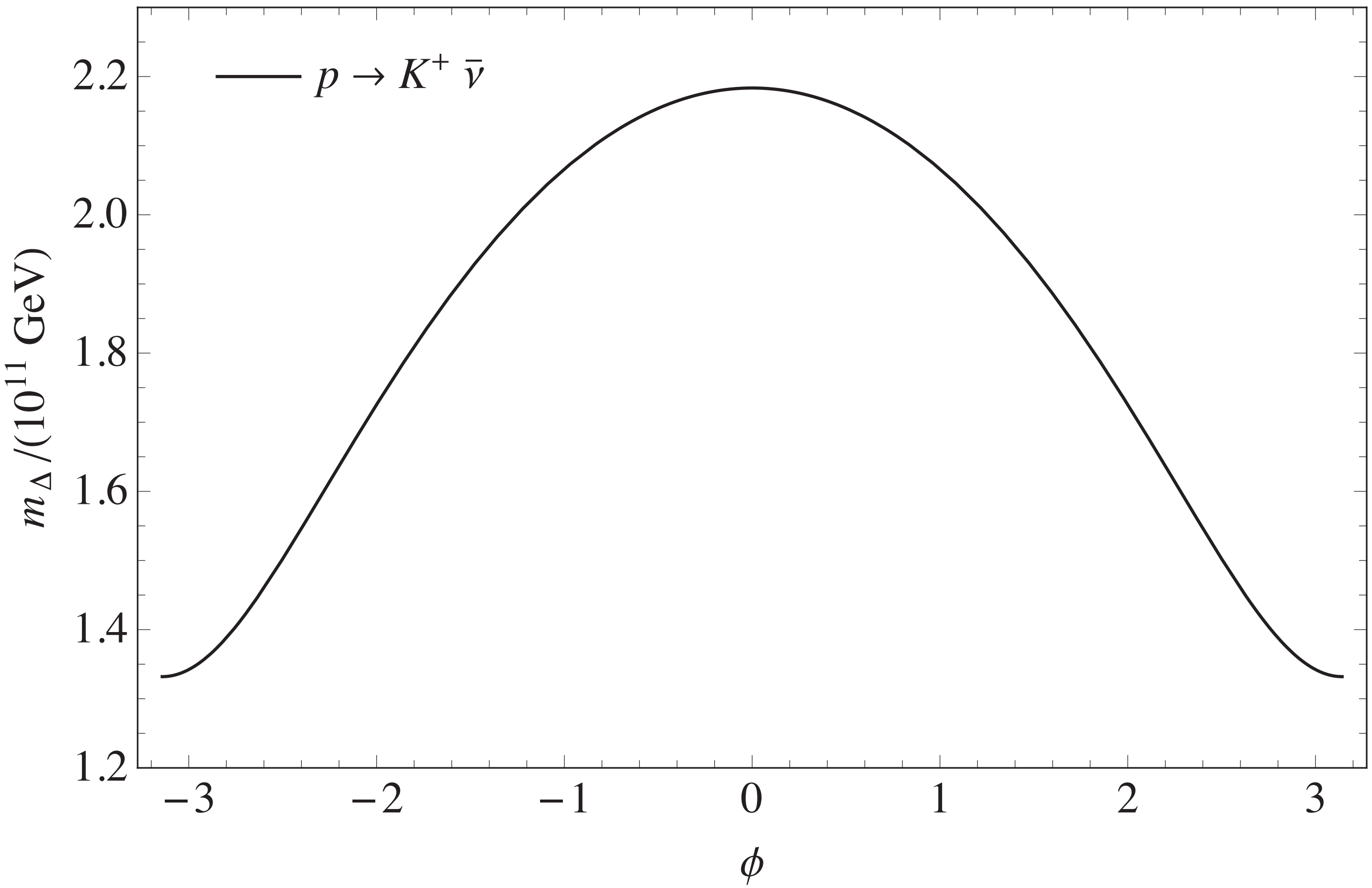
(MINIMAL VIABLE *SU*(5))

$$\Gamma_{p\to\pi^+\bar{\nu}} \sim (m_u^2 + m_d^2 + 2m_u m_d \cos\phi)m_d^2$$

$$\Gamma_{p\to K^+\bar{\nu}} \sim (m_u^2 + m_d^2 + 2m_u m_d \cos\phi)m_s^2$$

PREDICTIONS

(MINIMAL VIABLE $SU(5)$)



PREDICTIONS
(MINIMAL VIABLE *SU*(5))

$$m_\Delta > 2.2 \times 10^{11}\ \mathrm{GeV}$$

$$\Gamma_{p \to \pi^+ \bar{\nu}} / \Gamma_{p \to K^+ \bar{\nu}} = 10^{-2}$$

CONCLUSIONS

Predictions of the minimal viable version of $SU(5)$ for the two-body p-decay modes induced through scalar leptoquark exchange exhibit minimal (one-phase only) model dependence for $p \to K^+ \bar{\nu}$ and $p \to \pi^+ \bar{\nu}$ channels.

There exists an accurate limit on the mass of the scalar leptoquark.

The ratio of p-decay widths for channels with π^+ and K^+ in the final state is phase independent and predicts strong suppression of the former width with respect to the latter one.

THANK YOU!

CONTACT E-MAIL:

ILJA.DORSNER@IJS.SI