PHENO 2012, Pittsburgh, May 7 2012

Low-energy imprints of extended gauge symmetries

Michal Malinský

AHEP group of IFIC, CSIC/University of Valencia

based on

Phys.Rev. D 84, 053012 (2011)
JHEP02 (2012) 084
Nucl.Phys. B 854 (2012) 28

in collaboration with
Renato Fonseca, Martin Hirsch, Valentina de Romeri, Werner Porod, Lazslo Reichert, Florian Staub

Extended gauge symmetries

EW scale

Extended gauge symmetries

Planck scale

EW scale

Extended gauge symmetries

Planck scale

His sunt dragones

EW scale

Extended gauge symmetries

Planck scale

His sunt dragones

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low-scale extended gauge symmetries?

See talks by

M.Bishara
D.Duffty
R.Ruiz

and others

EW scale

Extended gauge symmetries

Planck scale

See talks by
almost anyone in Higgs & SUSY
sessions of PHENO'12

e.g.

R.Huo
and many others

low-scale extended
gauge symmetries?

SUSY @ TeV scale

EW scale

Extended gauge symmetries

Planck scale

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A. Elsayed, S. Khalil and S. Moretti
arXiv:1106.2130 [hep-ph]

M.Hirsch, MM, W.Porod, L.Reichert
JHEP02 (2012) 084

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high-scale extended gauge symmetries?

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unified dynamics ? GUT scale ?

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SUSY breaking

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SUSY @ TeV scale

soft SUSY sector

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unified dynamics ?

GUT scale ?

SUSY breaking

Majorana neutrino masses ?

Seesaw scale ?

Borzumati, Masiero

SUSY @ TeV scale

soft SUSY sector

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Extended gauge symmetries

Planck scale

unified dynamics ?

GUT scale ?

SUSY breaking

$SU(2)_R \times U(1)_{BL}$

SUSY @ TeV scale

EW scale

soft SUSY sector

Extended gauge symmetries

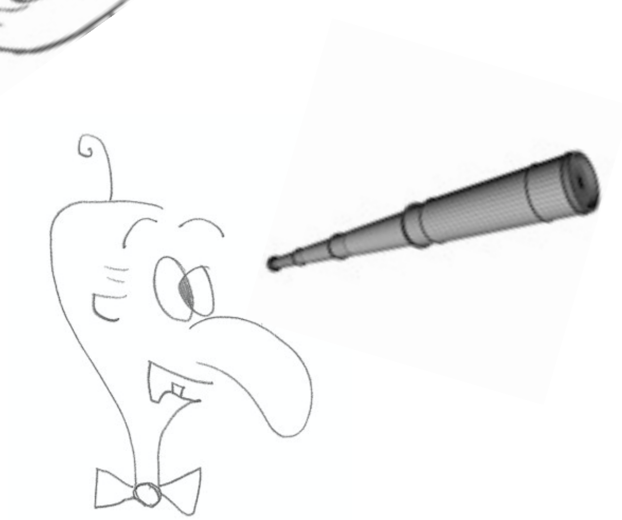
Planck scale

SUSY breaking

unified dynamics ?

GUT scale ?

$SU(4)_{PS} \times SU(2)_L \times SU(2)_R$



SUSY @ TeV scale

EW scale

Leading-log mSUGRA RG invariants

$$m^2_{\tilde{f}}(M_{\rm SUSY}) = m_0^2 + \frac{M_{1/2}}{\alpha(M_{\rm G})^2} \sum_S \sum_{i=1}^{N_S} F^i_{\tilde{f},S} \alpha_i(v_S^<)^2$$

$$M_i(M_{\rm SUSY}) = M_{1/2} \frac{\alpha_i(M_{\rm SUSY})}{\alpha(M_G)}$$

$$F^i_{\tilde{f},S} = \frac{c^i_{\tilde{f},S}}{b_i} \left\{1 - \left[\alpha_i(v_S^<)/\alpha_i(v_S^>)\right]^2\right\}$$

$$c^i_{\tilde{f},S} = 2C_{G_i^S}(R_f)$$

Leading-log mSUGRA RG invariants

$$m_{\tilde{f}}^2(M_{\rm SUSY}) = m_0^2 + \frac{M_{1/2}}{\alpha(M_{\rm G})^2}\sum_S \sum_{i=1}^{N_S} F^i_{\tilde{f},S}\,\alpha_i(v_S^<)^2$$

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$$(m^2_{\tilde{A}} - m^2_{\tilde{B}})/M_i^2$$

independent on mSUGRA parameters at the leading log level

S. P. Martin and P. Ramond, Phys. Rev. D 48, 5365 (1993).

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G. A. Blair, W. Porod, and P. M. Zerwas,
Phys. Rev. D 63, 017703 (2000)
P. Bechtle, K. Desch, W. Porod, and P. Wienemann,
Eur. Phys. J. C 46, 533 (2006)
R. Lafaye, T. Plehn, M. Rauch, and D. Zerwas,
Eur. Phys. J. C 54, 617 (2008)
...

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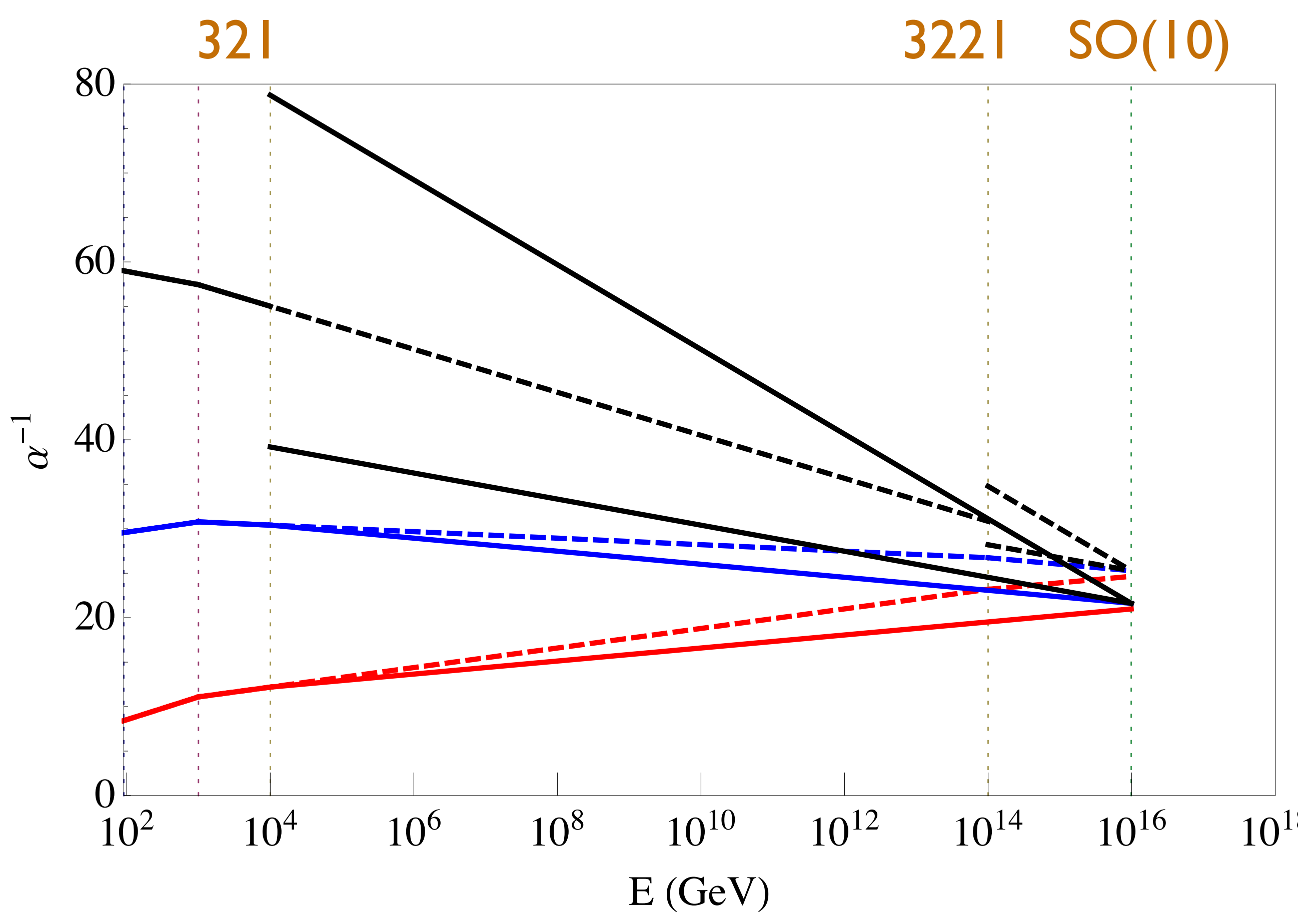
Example: sliding left-right scale

extra vector-like down-type quarks

	#	$3_c 2_L 2_R 1_{B-L}$	$SO(10)$
Matter	3	$(3, 2, 1, +\frac{1}{3})$	16
	3	$(\bar{3}, 1, 2, -\frac{1}{3})$	16
	3	$(1, 2, 1, -1)$	16
	3	$(1, 1, 2, +1)$	16
	3	$(1, 1, 1, 0)$	1
	1	$(3, 1, 1, -\frac{2}{3}),\ (\bar{3}, 1, 1, +\frac{2}{3})$	10
Higgs	1	$(1, 2, 2, 0)$	10, 120
	1	$(1, 2, 1, \pm 1)$	$\overline{16}$, 16
	3	$(1, 1, 2, \mp 1)$	$\overline{16}$, 16



V. DeRomeri, M.Hirsch, MM, L.Reichert
Phys.Rev. D 84, 053012 (2011)

a variant of

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	1	$(3,1,1,-\frac{2}{3}),\ (\bar{3},1,1,+\frac{2}{3})$	10
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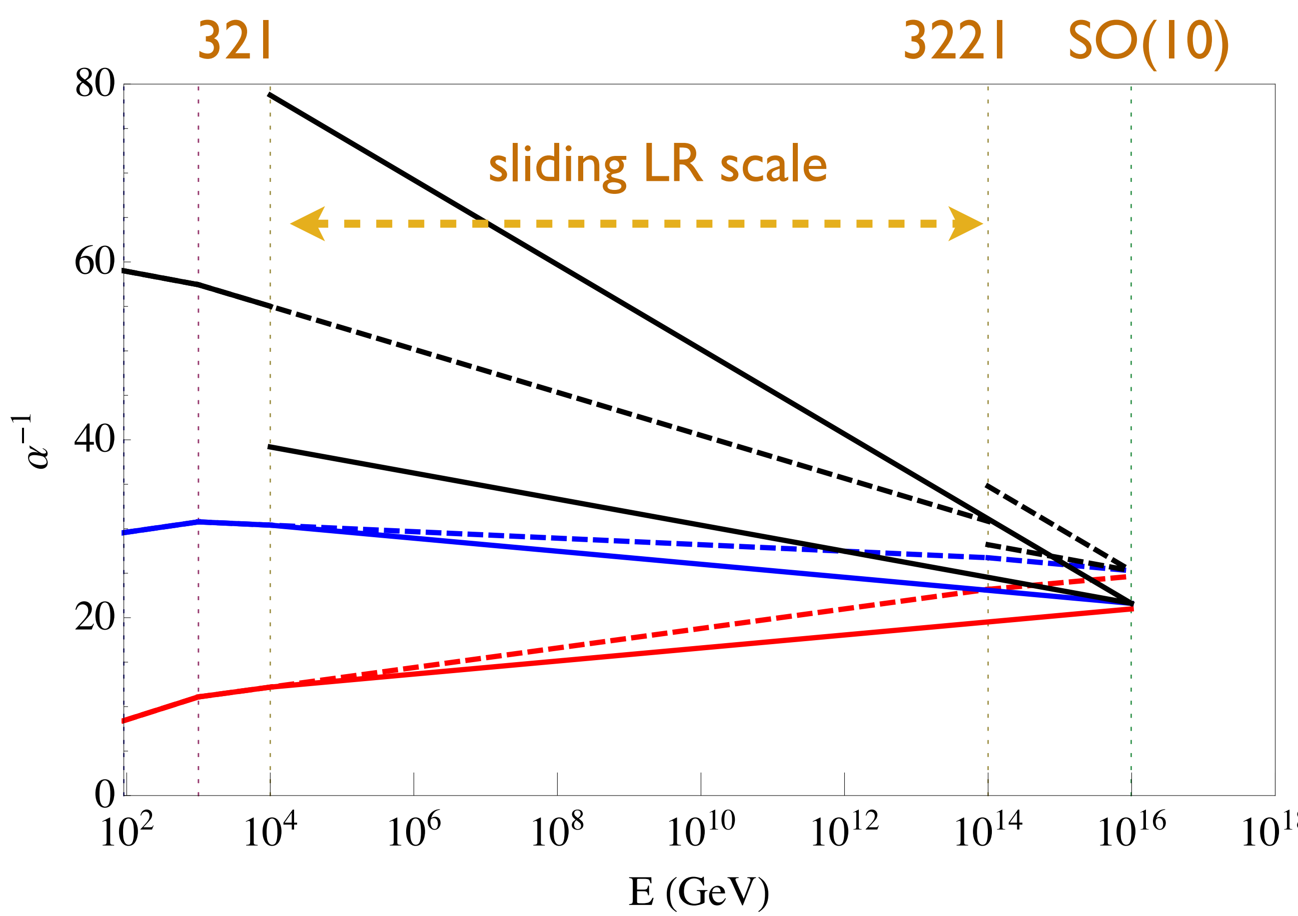

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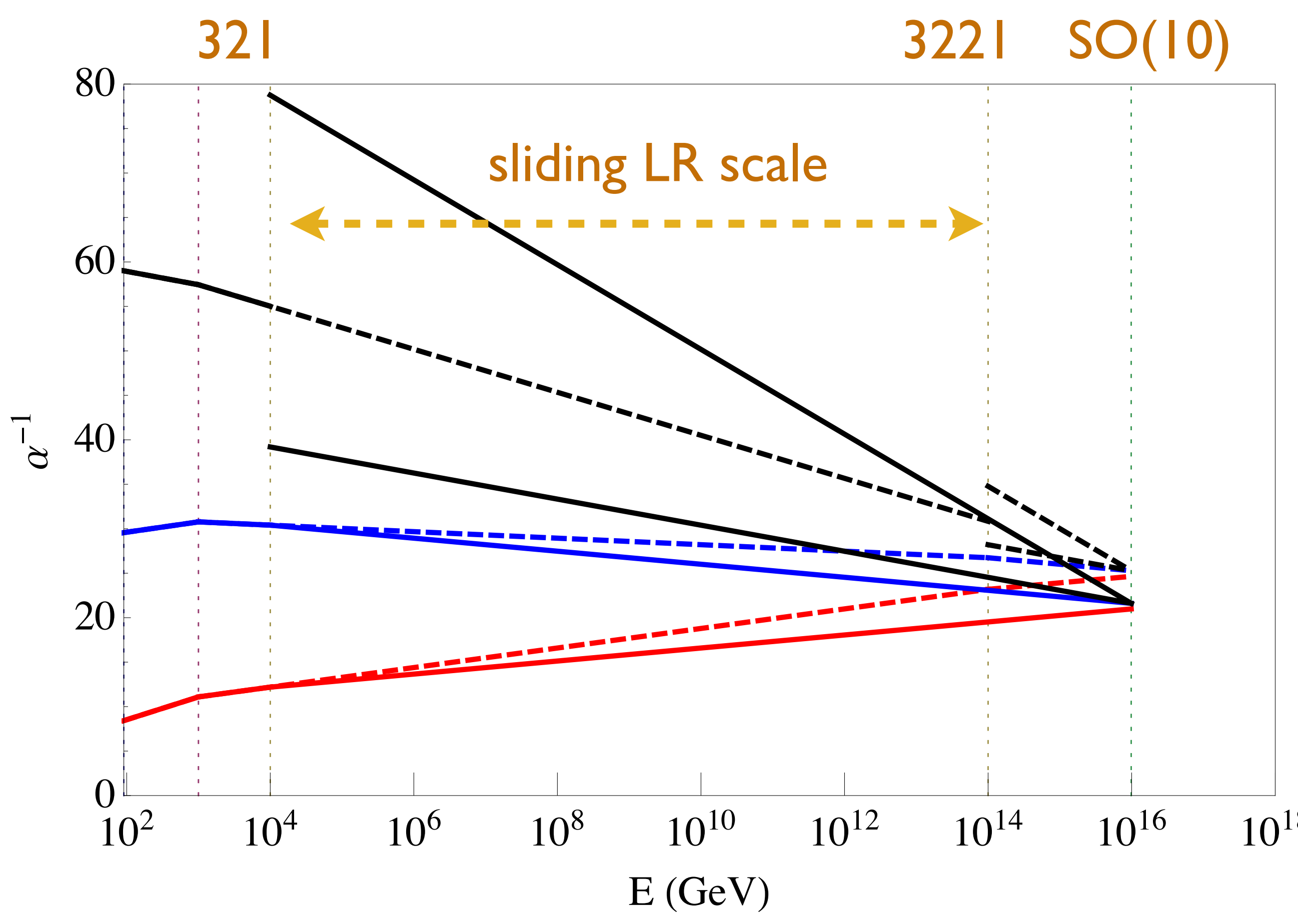

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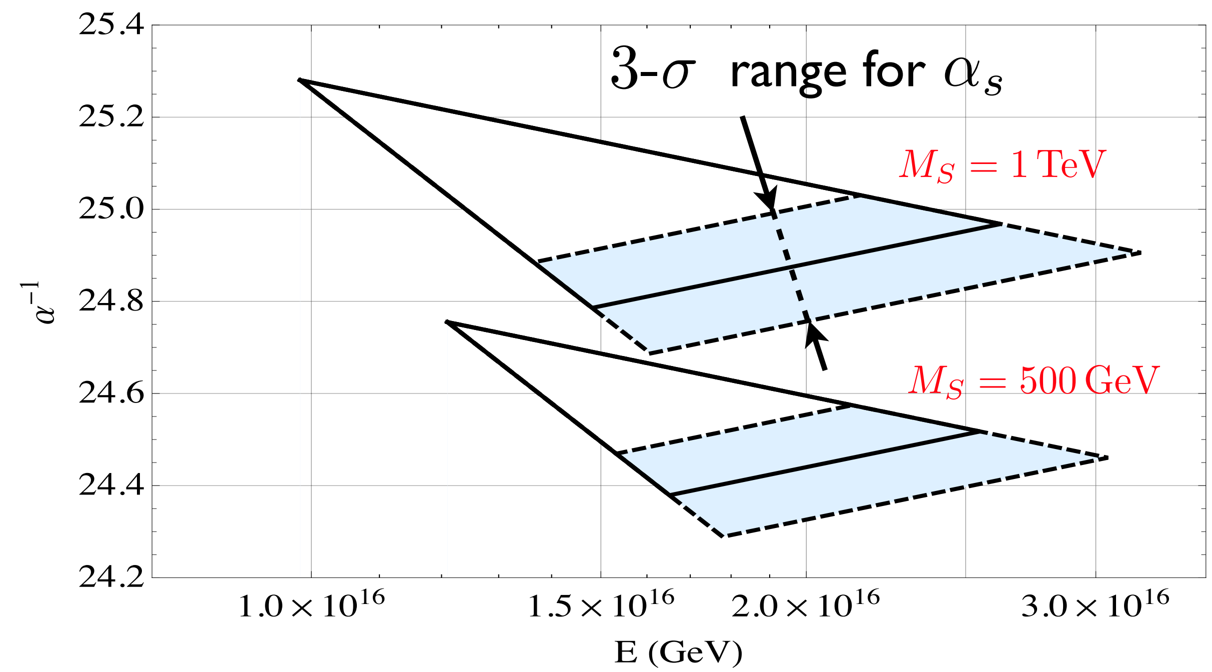

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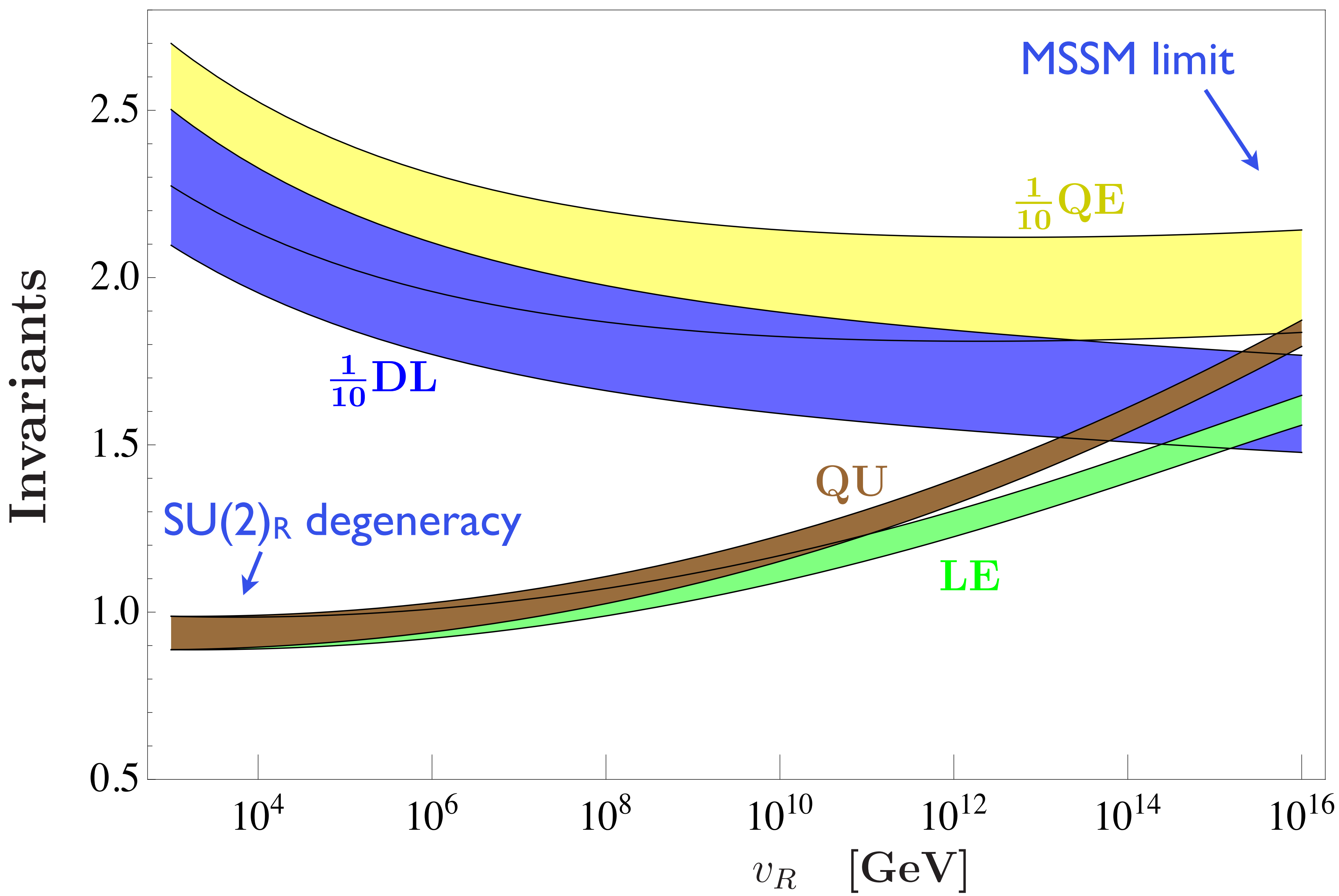

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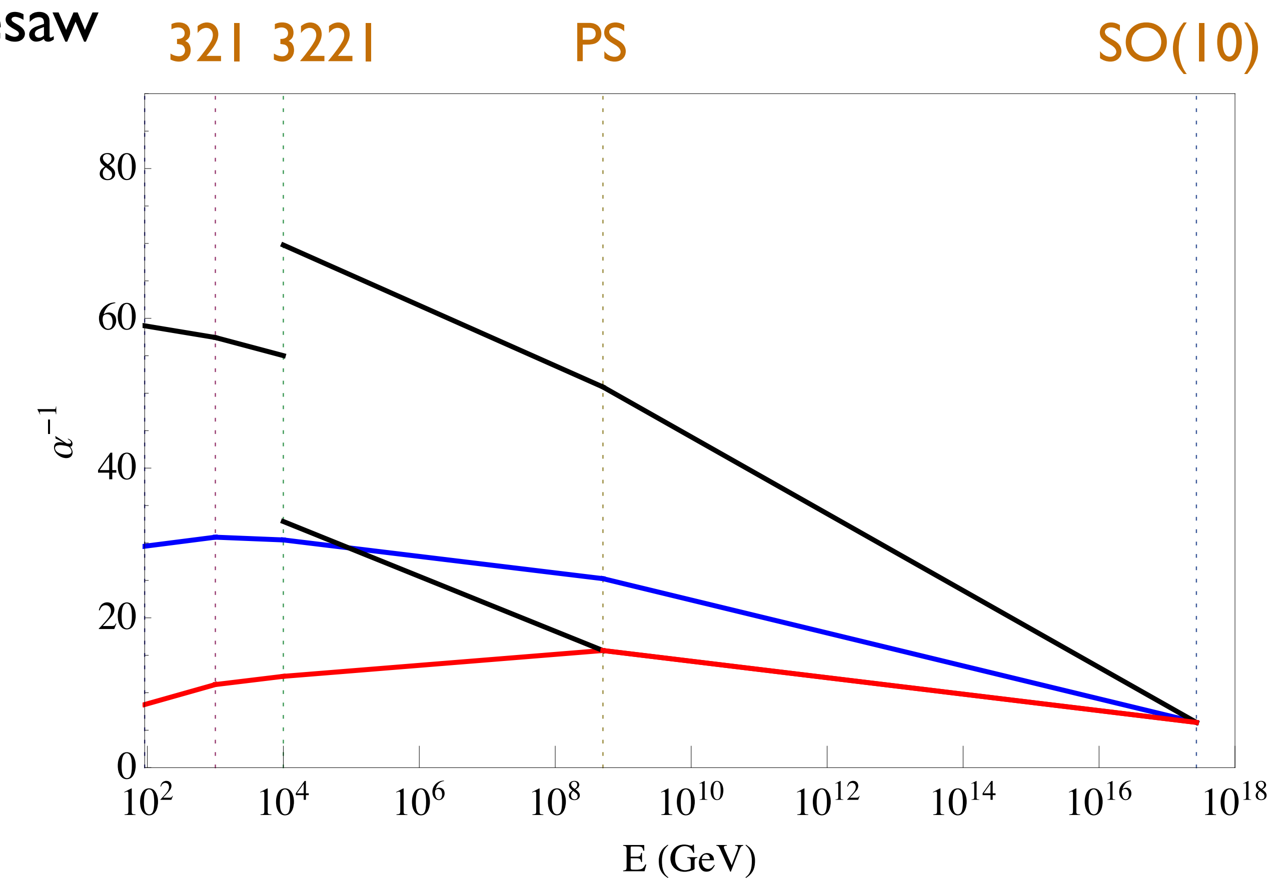
sliding LR scale

V. DeRomeri, M.Hirsch, MM, L.Reichert
Phys.Rev. D 84, 053012 (2011)

Example: sliding Pati-Salam & LR scales

extra vector-like down-type quarks, "exotic" seesaw

	#	$3_c 2_L 2_R 1_{B-L}$	$4_C 2_L 2_R$	$SO(10)$
Matter	3	$(3,2,1,+\frac{1}{3})$	$(4,2,1)$	16
	3	$(\bar{3},1,2,-\frac{1}{3})$	$(\bar{4},1,2)$	16
	3	$(1,2,1,-1)$	$(4,2,1)$	16
	3	$(1,1,2,+1)$	$(\bar{4},1,2)$	16
	3	$(1,1,3,0)$	$(1,1,3)$	45
	1	$(3,1,1,\mp\frac{2}{3})$	$(6,1,1)$	10
Higgs	2	$(1,2,2,0)$	$(1,2,2)$	10
	1	$(1,1,3,0)$	$(1,1,3)$	45
	1	$(1,2,1,\pm 1)$	$(\bar{4},2,1)$,$(4,2,1)$	$\overline{16}$, 16
	1	$(1,1,2,\mp 1)$	$(4,1,2)$,$(\bar{4},1,2)$	$\overline{16}$, 16
	1	absent	$(15,1,1)$	45



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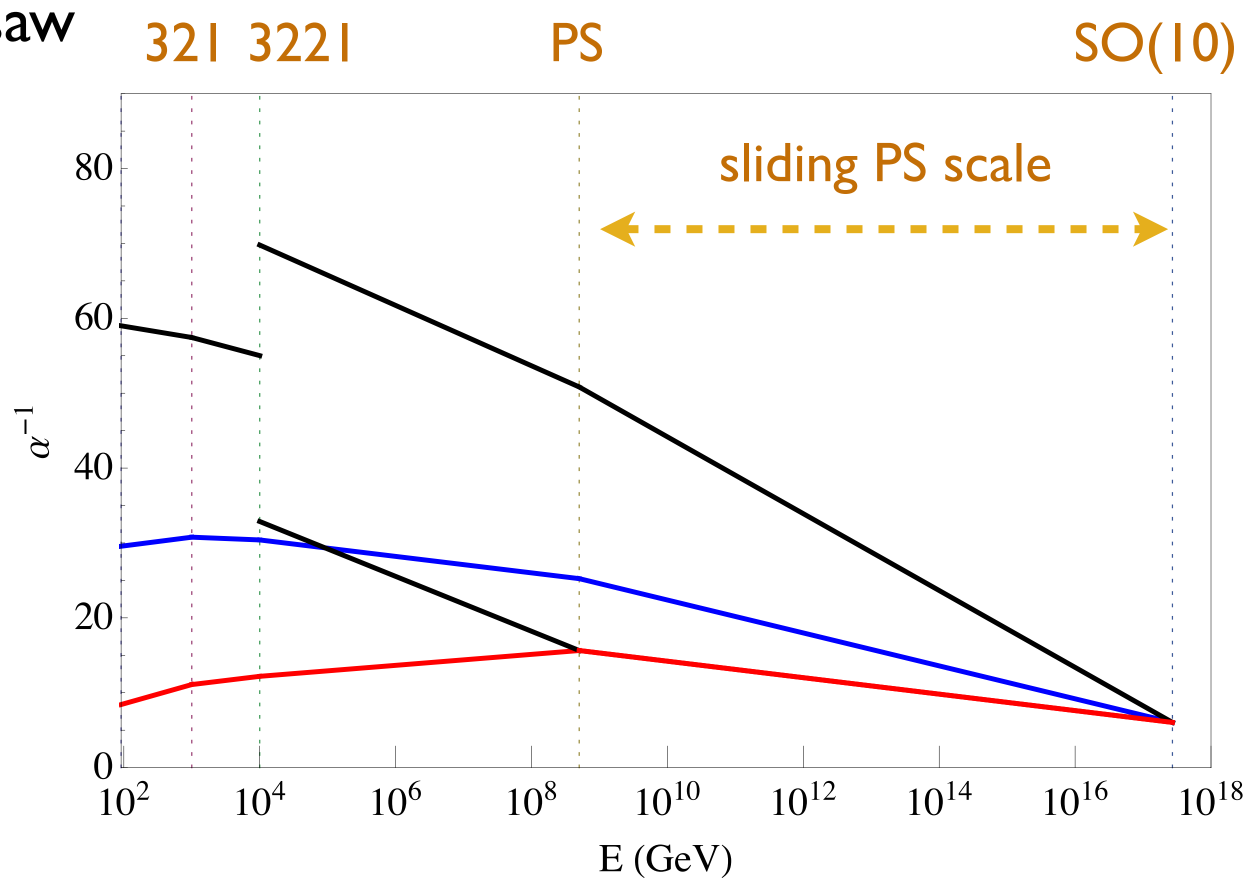

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	3	$(1, 1, 2, +1)$	$(\bar{4}, 1, 2)$	16
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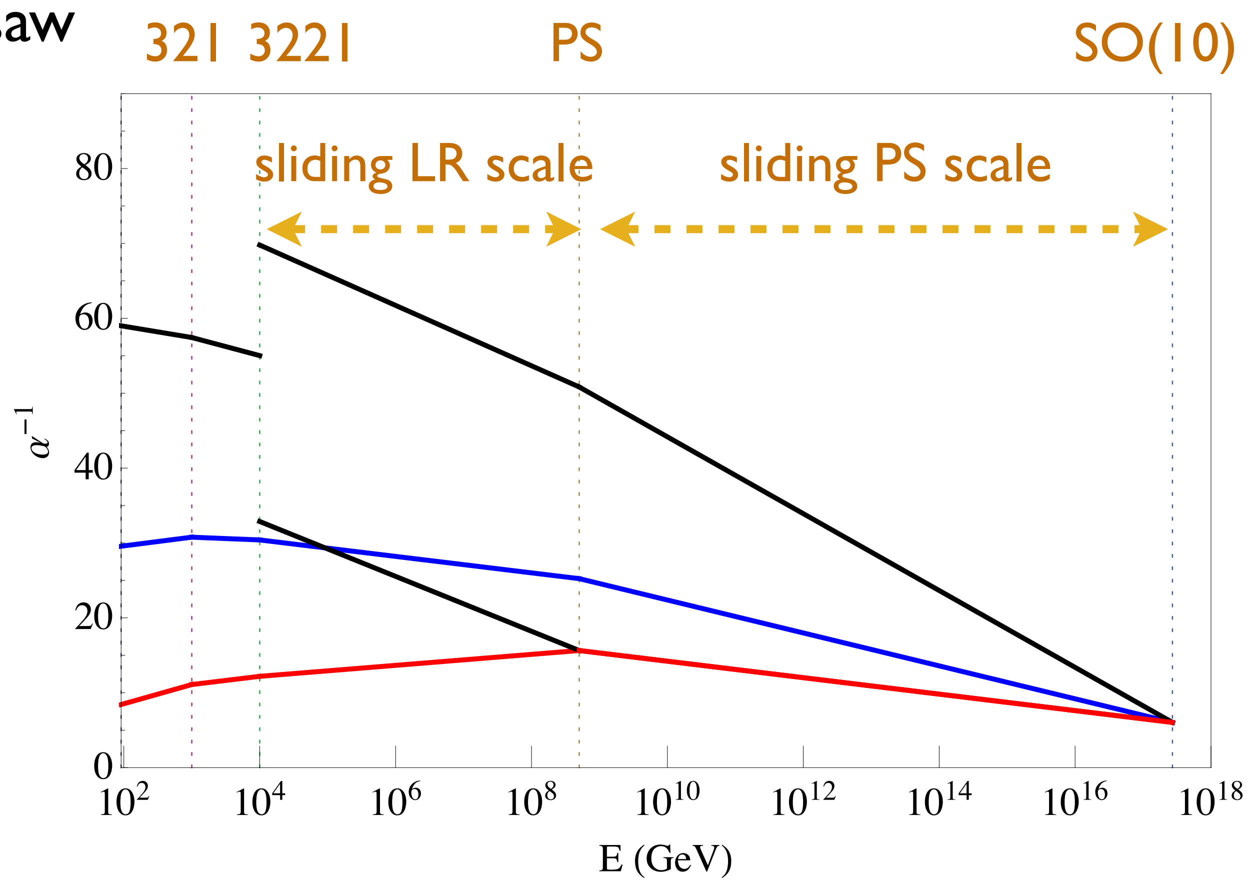

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	1	$(1, 1, 2, \mp 1)$	$(4, 1, 2)$,$(\bar{4}, 1, 2)$	$\overline{16}$, 16
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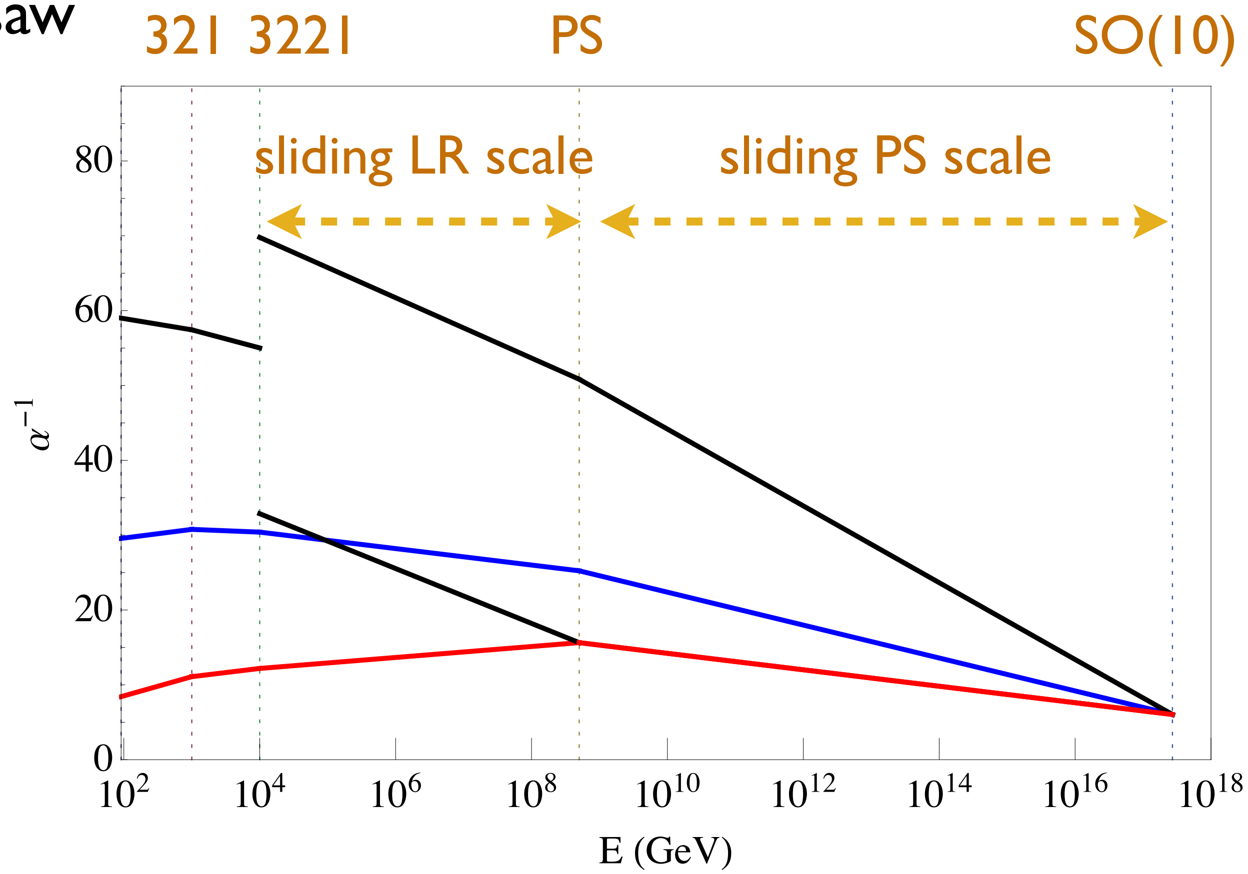

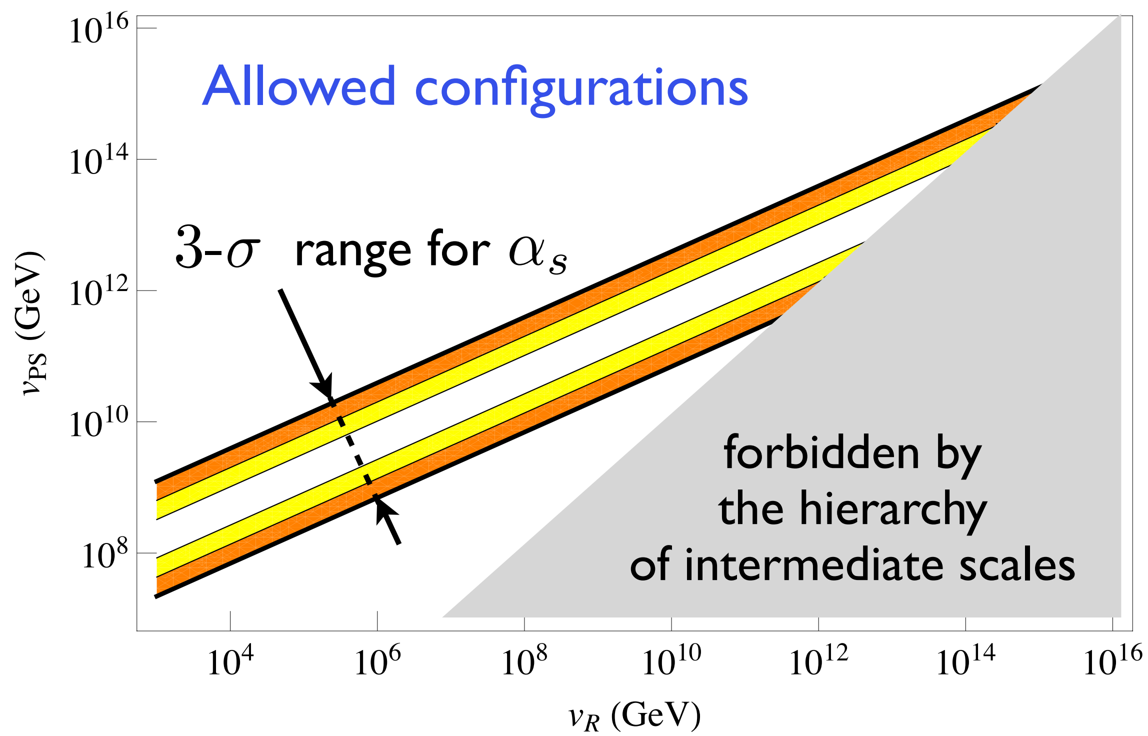

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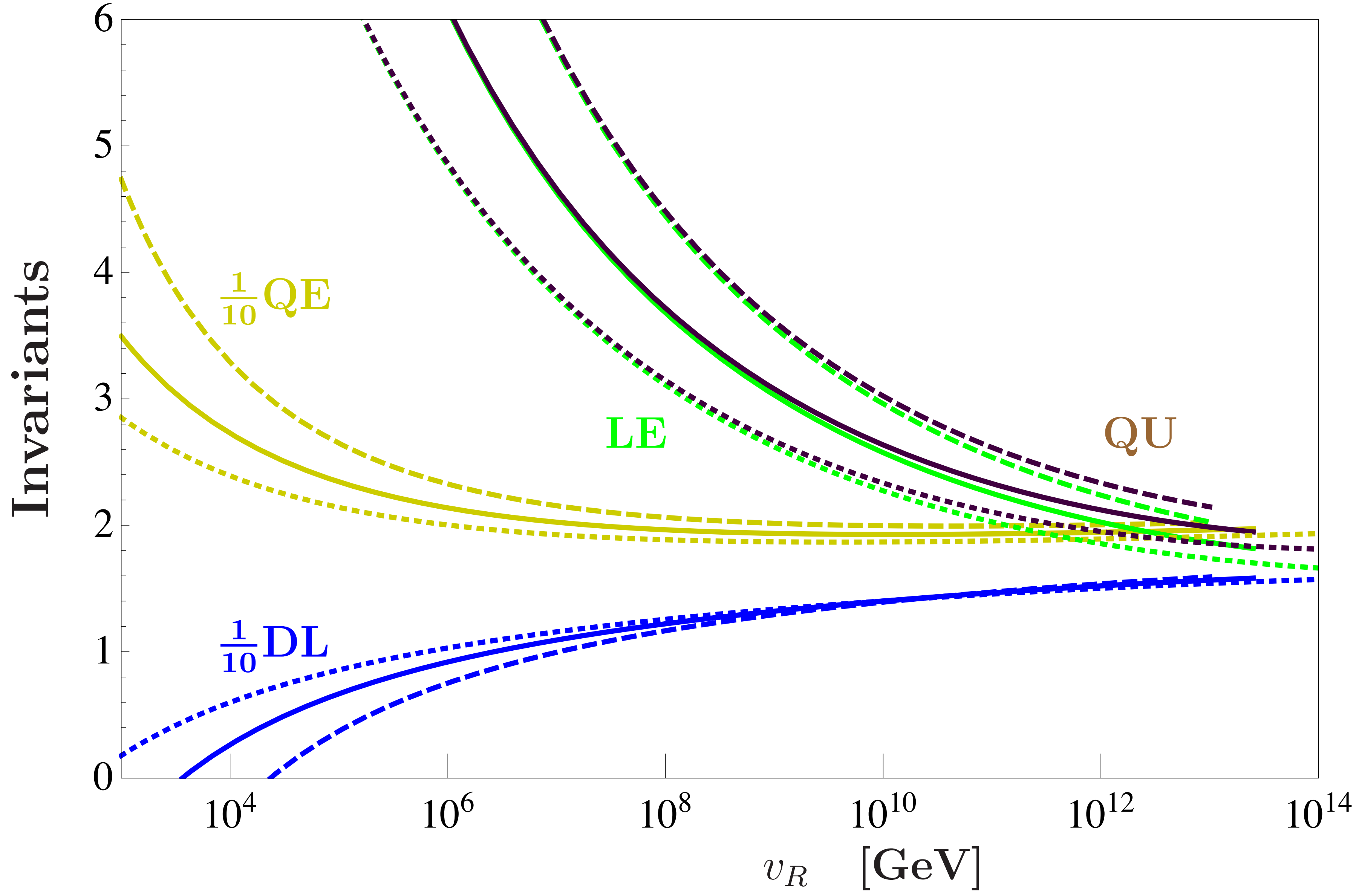

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PS scale from 10^8 GeV to 10^{16} GeV

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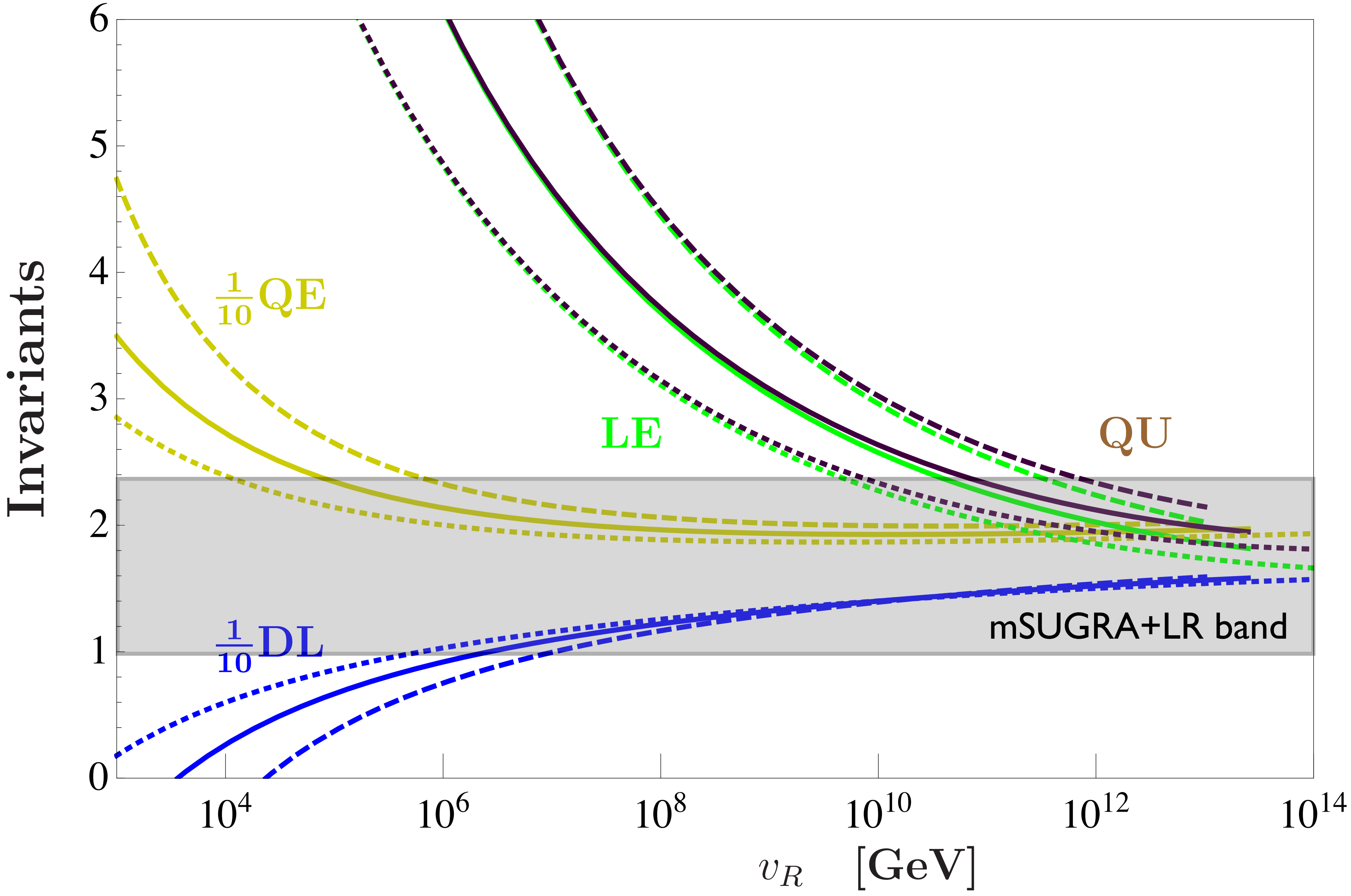

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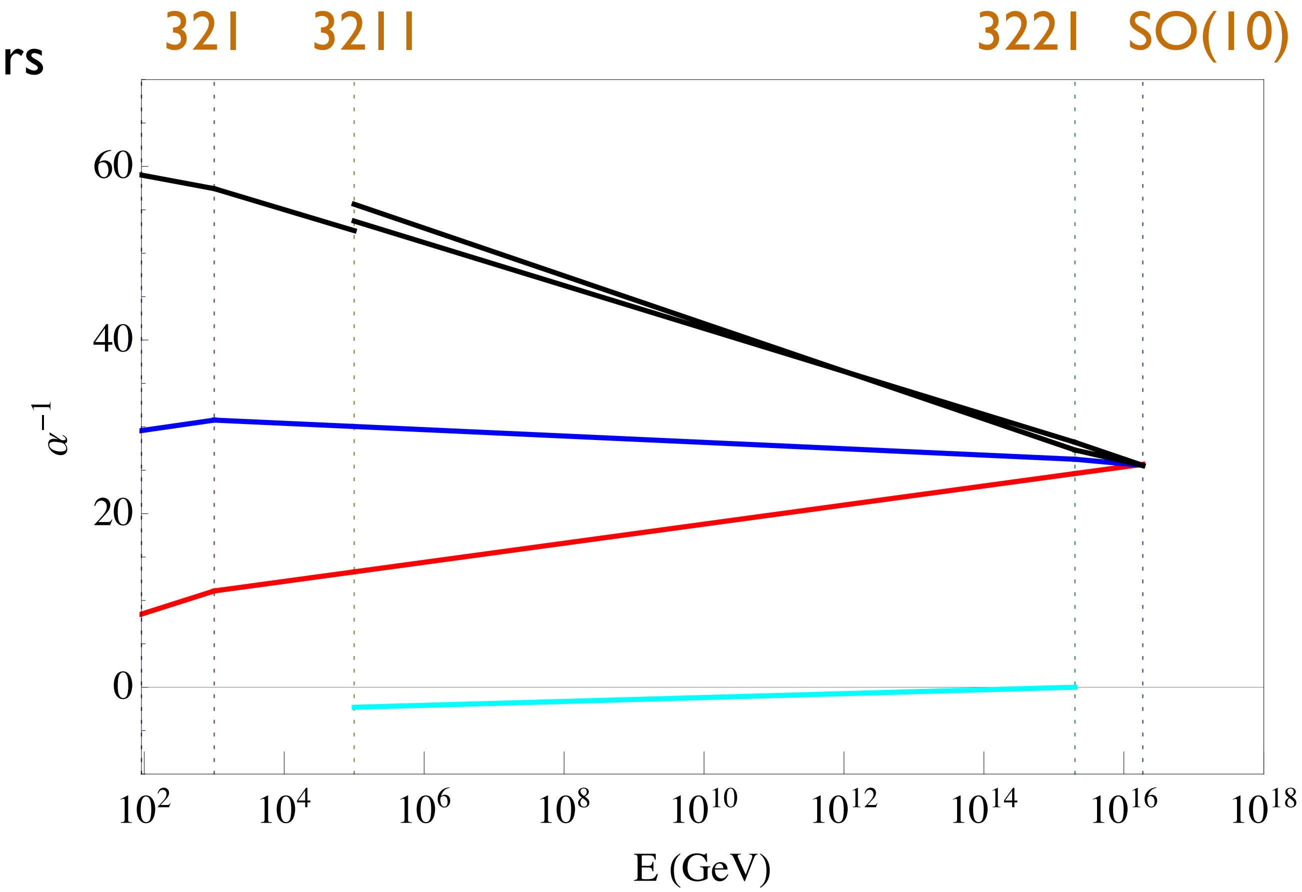
Anti-example: sliding $U(1)_R \times U(1)_{BL}$

minimally finetuned setting with a pair of Abelian factors

	#	$3_c 2_L 1_R 1_{B-L}$	$3_c 2_L 2_R 1_{B-L}$	$SO(10)$
Matter	3	$(3, 2, 0, +\frac{1}{3})$	$(3, 2, 1, +\frac{1}{3})$	16
	3	$(\bar{3}, 1, \pm\frac{1}{2}, -\frac{1}{3})$	$(\bar{3}, 1, 2, -\frac{1}{3})$	16
	3	$(1, 2, 0, -1)$	$(1, 2, 1, -1)$	16
	3	$(1, 1, \pm\frac{1}{2}, +1)$	$(1, 1, 2, +1)$	16
	3	$(1, 1, 0, 0)$	$(1, 1, 1, 0)$	1
Higgs	2	$(1, 2, \pm\frac{1}{2}, 0)$	$(1, 2, 2, 0)$	10
	1	absent	$(1, 1, 3, 0)$	45
	1	absent	$(1, 2, 1, \pm 1)$	$\overline{16}$, 16
	1	$(1, 1, \pm\frac{1}{2}, \mp 1)$	$(1, 1, 2, \mp 1)$	$\overline{16}$, 16

MM, J. C. Romao, and J.W. F.Valle
Phys. Rev. Lett. 95, 161801 (2005)



Anti-example: sliding U(1)R x U(1)BL

minimally finetuned setting with a pair of Abelian factors

	#	$3_c 2_L 1_R 1_{B-L}$	$3_c 2_L 2_R 1_{B-L}$	$SO(10)$
Matter	3	$(3,2,0,+\frac{1}{3})$	$(3,2,1,+\frac{1}{3})$	16
	3	$(\bar{3},1,\pm\frac{1}{2},-\frac{1}{3})$	$(\bar{3},1,2,-\frac{1}{3})$	16
	3	$(1,2,0,-1)$	$(1,2,1,-1)$	16
	3	$(1,1,\pm\frac{1}{2},+1)$	$(1,1,2,+1)$	16
	3	$(1,1,0,0)$	$(1,1,1,0)$	1
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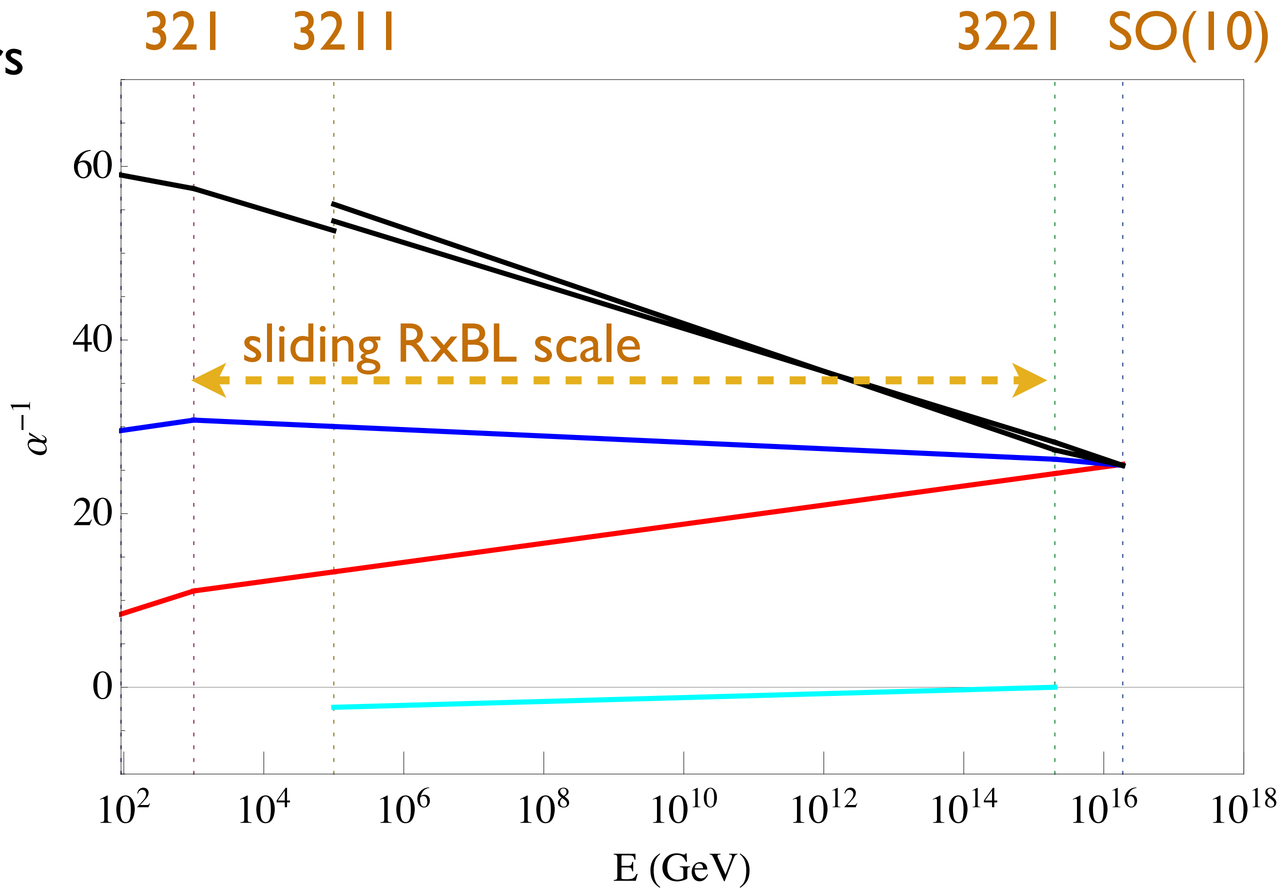

Anti-example: sliding U(1)$_R$ x U(1)$_{BL}$

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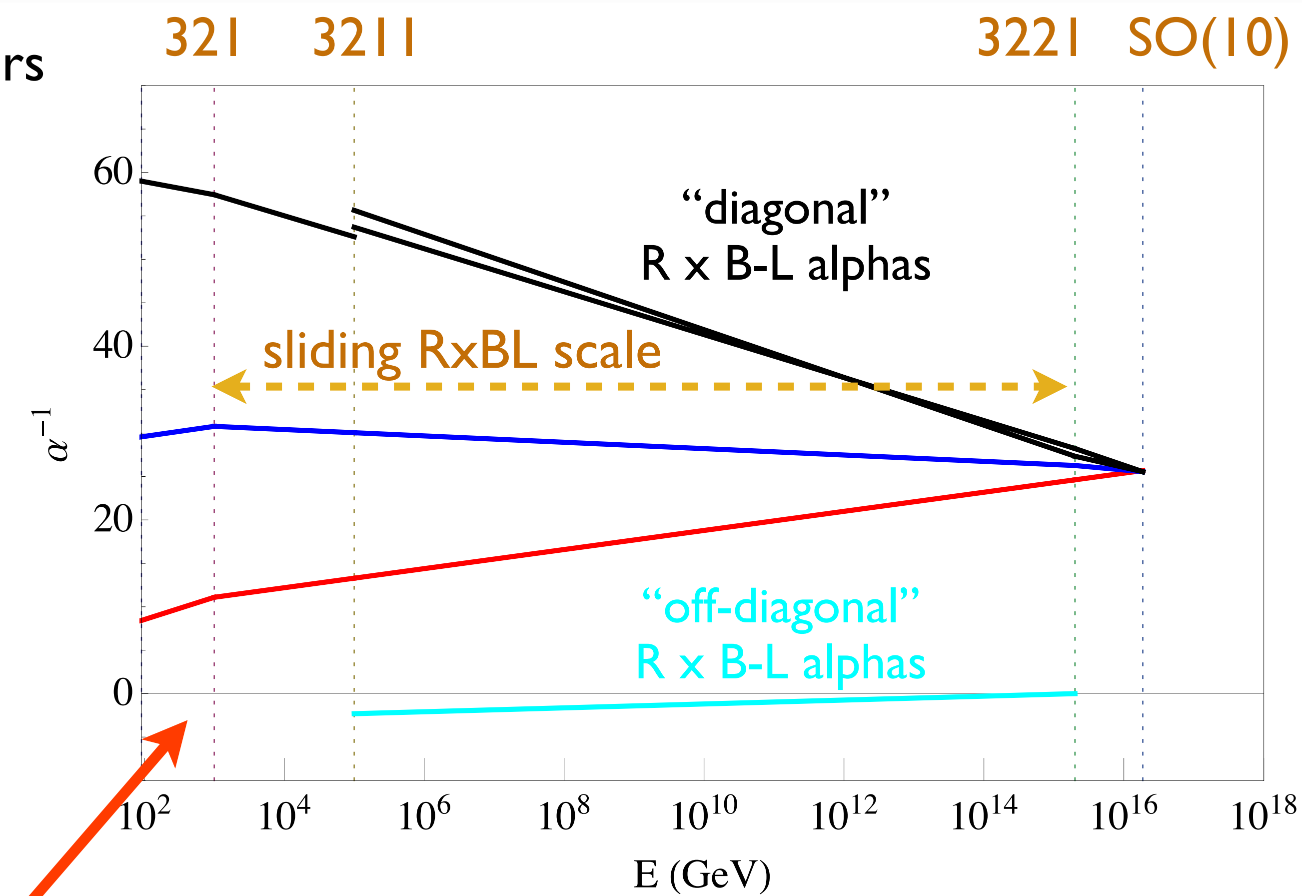

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Phys. Rev. Lett. 95, 161801 (2005)

The U(1) mixing is important here!

B. Holdom, F. del Aguila, G.D. Coughlan, M. Quiros
et al. in 1980's

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	3	$(1,1,\pm\frac{1}{2},+1)$	$(1,1,2,+1)$	16
	3	$(1,1,0,0)$	$(1,1,1,0)$	1
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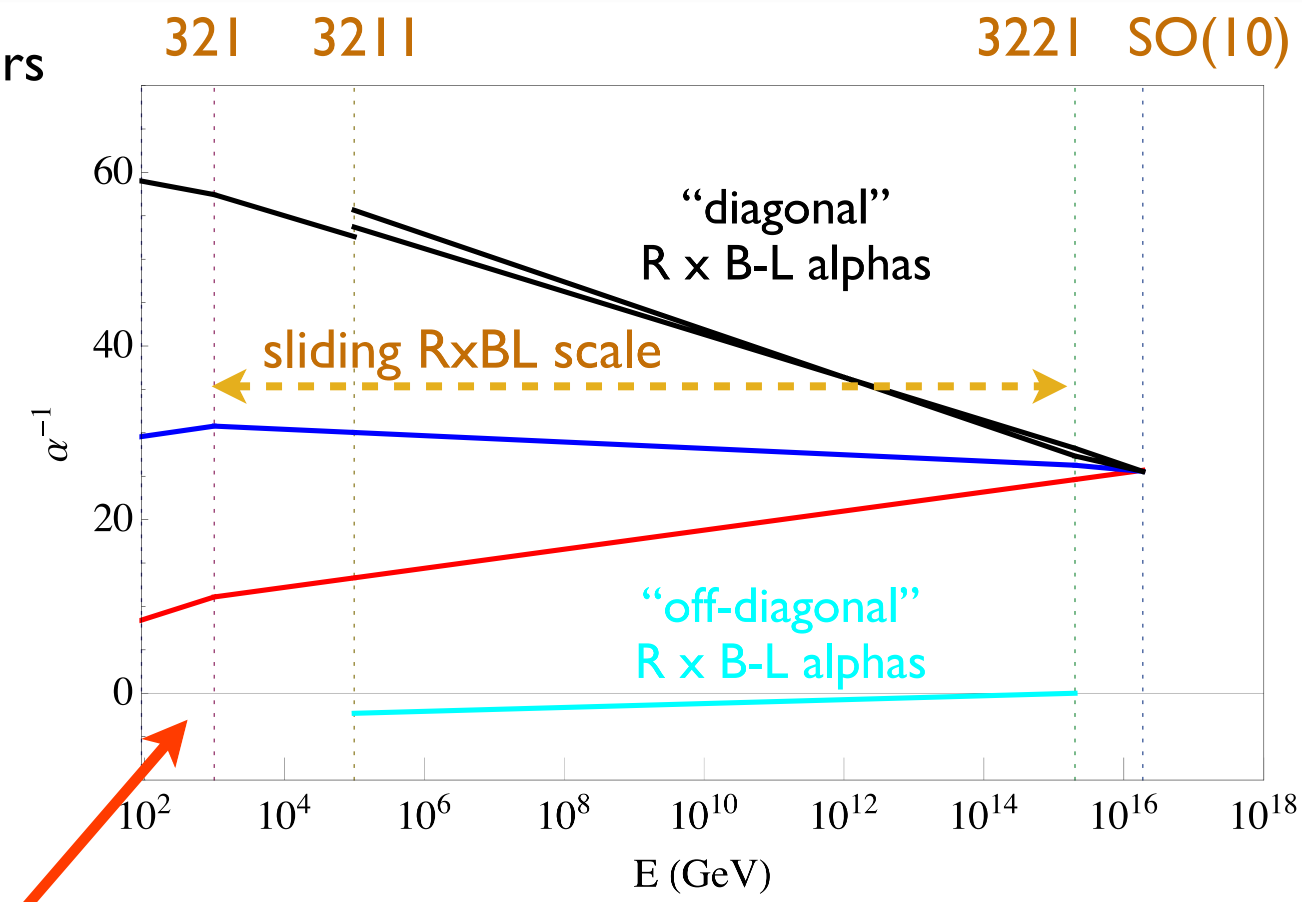
	1	absent	$(1,1,3,0)$	45
	1	absent	$(1,2,1,\pm1)$	$\overline{16}$, 16
	1	$(1,1,\pm\frac{1}{2},\mp1)$	$(1,1,2,\mp1)$	$\overline{16}$, 16

MM, J. C. Romao, and J. W. F. Valle
Phys. Rev. Lett. 95, 161801 (2005)



The U(1) mixing is important here!

B. Holdom, F. del Aguila, G.D. Coughlan, M. Quiros
et al. in 1980's

M.E. Machacek, M.T. Vaughn, Nucl. Phys. B 222 (1983) etc.

R. Fonseca, MM, W. Porod, and F. Staub
Nucl.Phys. B 854 (2012) 28

Anti-example: sliding $U(1)_R \times U(1)_{BL}$

minimally finetuned setting with a pair of Abelian factors

	#	$3_c2_L1_R1_{B-L}$	$3_c2_L2_R1_{B-L}$	$SO(10)$
Matter	3	$(3,2,0,+\frac{1}{3})$	$(3,2,1,+\frac{1}{3})$	16
	3	$(\bar{3},1,\pm\frac{1}{2},-\frac{1}{3})$	$(\bar{3},1,2,-\frac{1}{3})$	16
	3	$(1,2,0,-1)$	$(1,2,1,-1)$	16
	3	$(1,1,\pm\frac{1}{2},+1)$	$(1,1,2,+1)$	16
	3	$(1,1,0,0)$	$(1,1,1,0)$	1
Higgs	2	$(1,2,\pm\frac{1}{2},0)$	$(1,2,2,0)$	10
	1	absent	$(1,1,3,0)$	45
	1	absent	$(1,2,1,\pm1)$	$\overline{16}$, 16
	1	$(1,1,\pm\frac{1}{2},\mp1)$	$(1,1,2,\mp1)$	$\overline{16}$, 16

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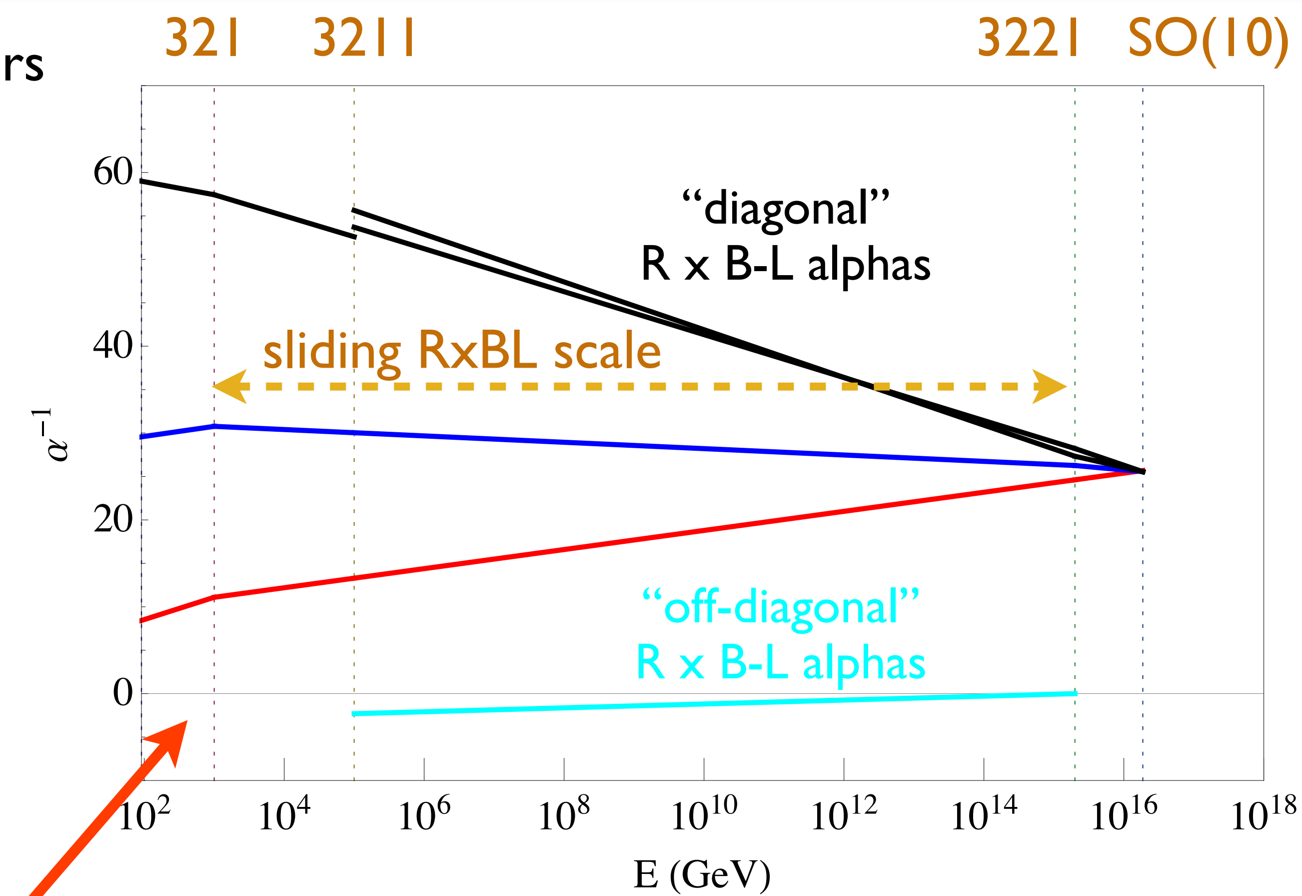
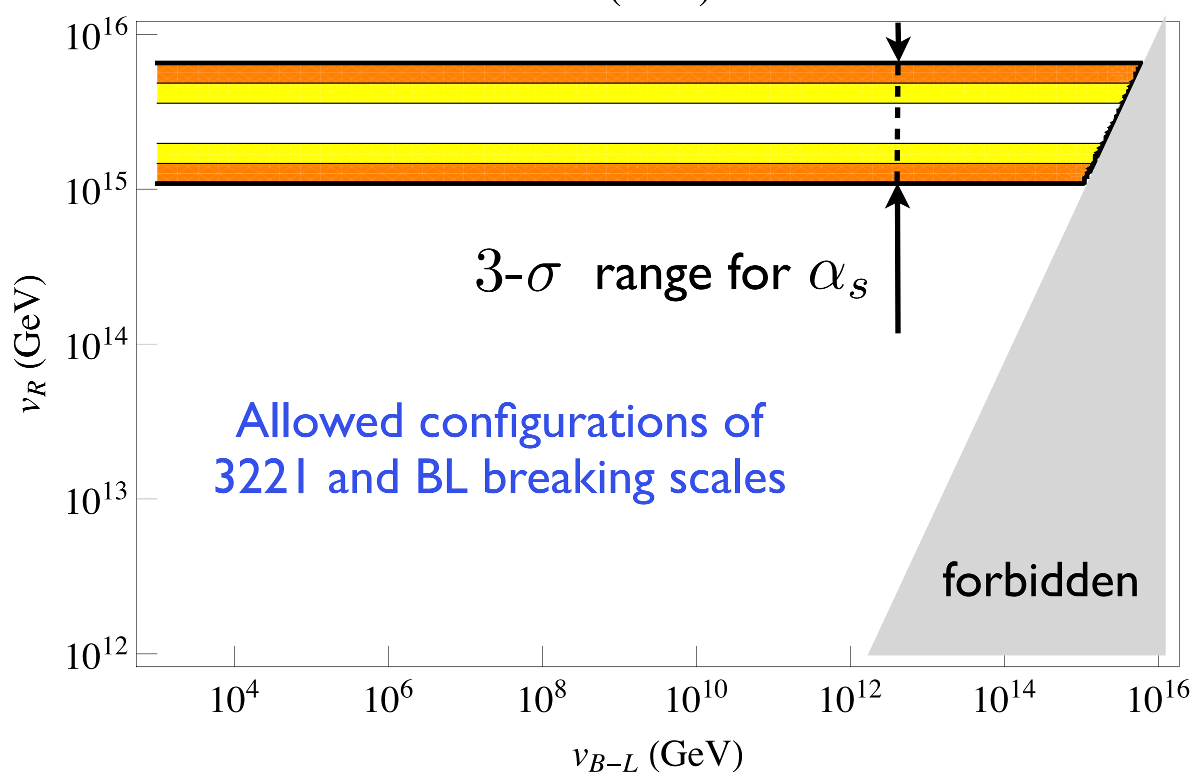
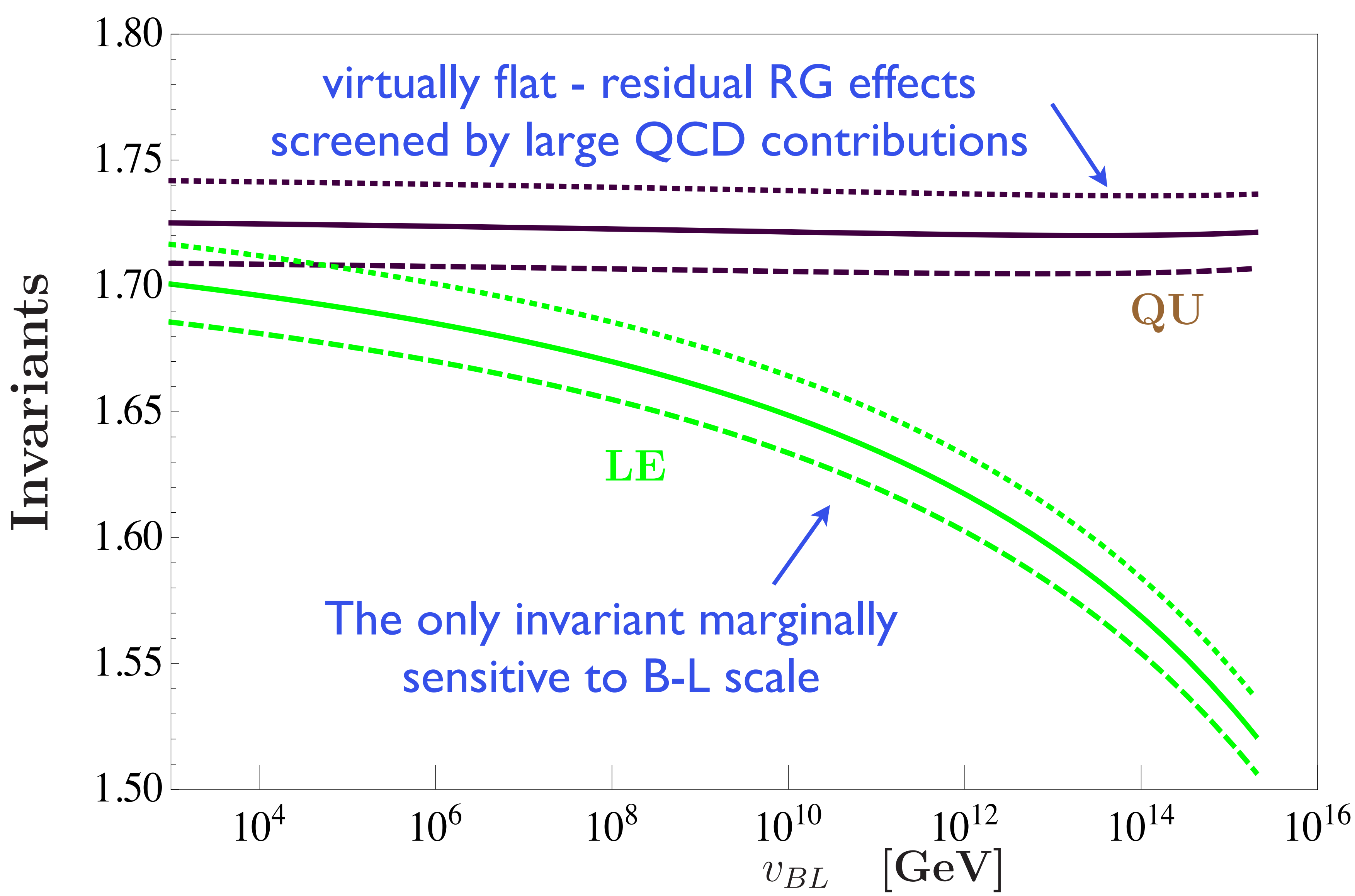




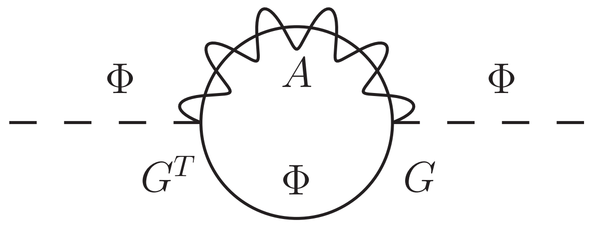
Anti-example: sliding $U(1)_R \times U(1)_{BL}$

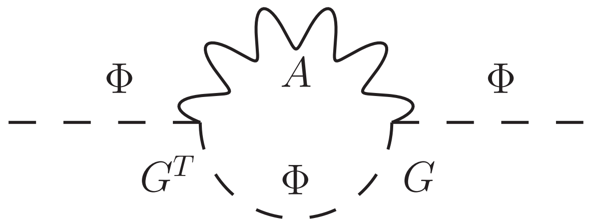


sliding $U(1)_R \times U(1)_{BL}$

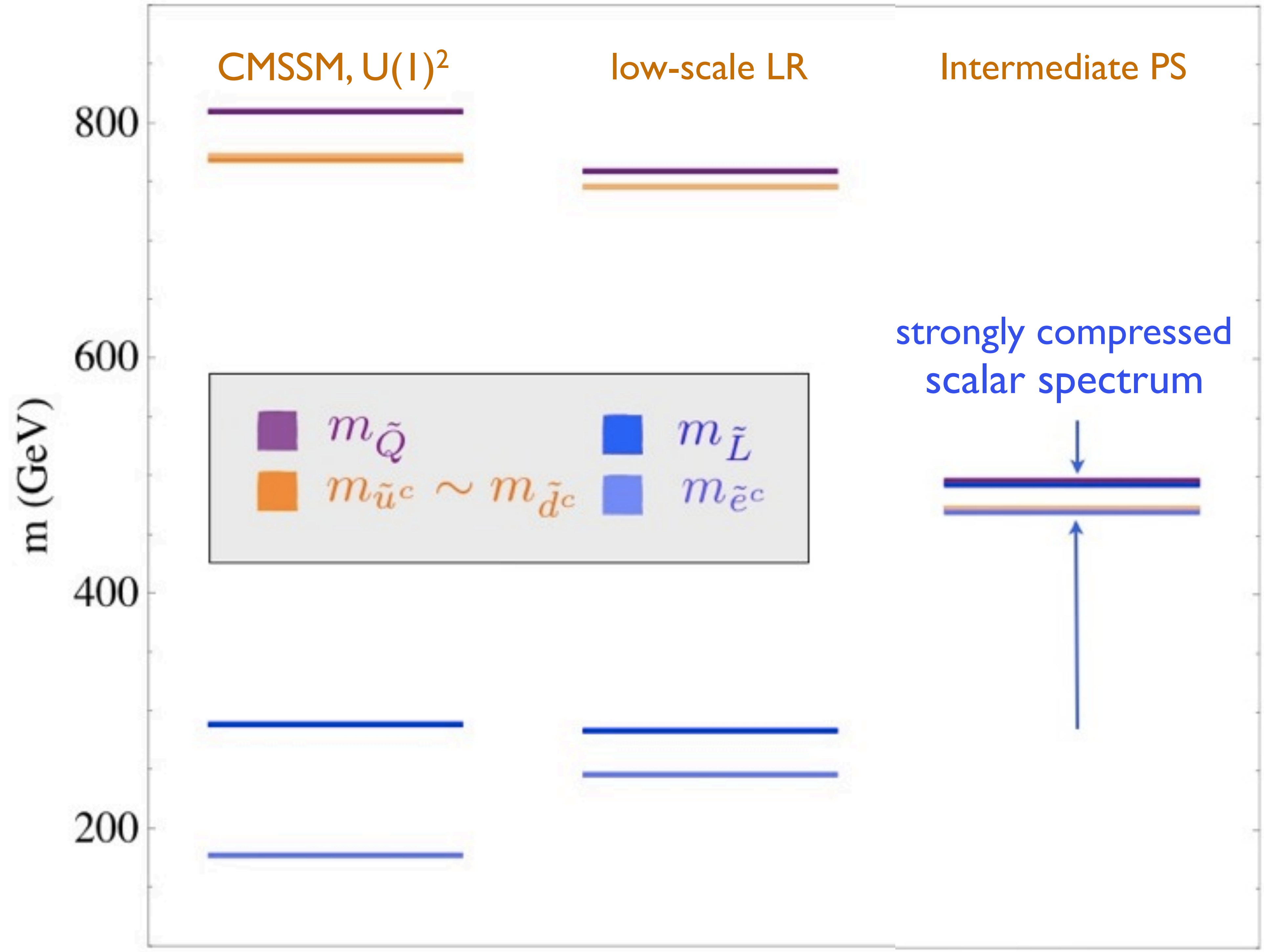
$$QU \equiv (m^2_{\tilde{Q}} - m^2_{\tilde{U}})/M_1^2$$

$$LE \equiv (m^2_{\tilde{L}} - m^2_{\tilde{E}})/M_1^2$$





The spectra



The MSSM soft squark and slepton spectra calculated for the SPS3 point ($m_0 = 90\text{GeV},\ M_{1/2} = 400\text{GeV}$) and $v_R = 10^3\text{GeV}$.

Few remarks

* Softs reconstruction is not straightforward - further inputs needed

* Sleptons and gauginos (if not too heavy) @ ILC - fantastic precision

* Squarks may be too heavy for ILC, be happy with LHC (if seen)

- long decay chains can be very helpful (few percent precision)

$$\tilde{q} \to \chi_2^0 q\,, \quad \chi_2^0 \to \tilde{l}^{\pm} l^{\mp} \to l^{\pm} l^{\mp} \chi_1^0$$

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* Disclaimer: it is extremely difficult to do all this in full glory!!!