On the Top-BESS Model:

Low-Energy Limit Updates

and

Reparameterization

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Outline

1 Introduction

2 Top-BESS Model

3 Low-Energy Limits

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ESB mechanism

- **EW symmetry is spontaneously broken** $\Rightarrow$ GB masses
- ESB mechanism = unsolved mystery of SM

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- **EW symmetry is spontaneously broken** $\Rightarrow$ GB masses
- ESB mechanism = unsolved mystery of SM
- benchmark hypothesis: Higgs doublet $\Rightarrow$ Higgs boson
- alternatives: SUSY, Technicolor
- newbies: AdS/CFT $\Rightarrow$ RS-like extra-dim theories, dual to TC

Reasons for new particles

Model Dependent

- SUSY: ... superpartners, Higgs-like scalars
- TC: ... bound states
- extra-dim: ... KK towers

Model InDependent

SM w/o Higgs violates unitarity $\approx$ 1 TeV

Reasons for effective description

1. $E \to \mathcal{O}(10^2)$ GeV : $\quad \mathcal{L}(\text{BSM}) \longrightarrow \mathcal{L}(\not{\text{H}}\text{SM})$
2. LHC will reach the lowest lying BSM resonances

$$\Downarrow$$

Effective Lagrangian

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BESS Model

... [Casalbuoni *et al*, PLB 155, 95 (1985)]

- global: $\boldsymbol{SU(2)_L \times SU(2)_R \times U(1)_{B-L} \times SU(2)_{HLS}}$
- local: $\boldsymbol{SU(2)_L \times SU(2)_Y \times SU(2)_{HLS}}$
- ~~H~~SM particles + $SU(2)_{HLS}$ gauge vector triplet $(\rho^0, \rho^\pm)$
- gauge equivalent to

$$[SU(2)_L \times SU(2)_R]/SU(2)_{L+R} \text{ non-linear sigma model}$$

$$+$$

$$SU(2)_{L+R} \text{ vector triplet [Weinberg'68]}$$

- universal fermion couplings: all gens. of given chirality

Intermezzo: ESB and Top Quark

- EW scale:

$$v \approx 250 \text{ GeV}$$

- top quark mass:

$$m_t \approx 170 \text{ GeV} \approx v/\sqrt{2}$$

- other fermion masses:

$$m_f \leq 1\% \, v$$

Top is ESB essential

- m_t, ESB ... interconnected
- ρ couples strongly to GB and top
- e.g. *Extended TC*

Top is not ESB essential

- m_t, ESB ... disconnected
- ρ couples strongly to GB only
- e.g. *Topcolor Assisted TC*

Top-BESS Model

ρ direct couplings to fermions:

- $SU(2)_{HLS}$ gauge coupling ... g''
- $(\mathrm{t,b})_L$ ... b_L
- t_R ... b_R
- b_R ... $\rho^{\pm}\mathrm{t}_R\mathrm{b}_R$: $p \cdot b_R$, $0 \leq p \leq 1$
  ... $\rho^0\mathrm{b}_R\mathrm{b}_R$: $p^2 \cdot b_R$

2 additional terms ... λ_L, λ_R

- *negligible at high energy*
- *relax low-energy limits*

Improving on parameterization

top-BESS Fermion Lagrangian (dim ≤ 4 operators)

$$\begin{aligned}\mathcal{L}_f \;=\; & \sum_{f=1,\ldots,5} \left[I_c^L(\psi_f) + I_c^R(\psi_f) - I_{mass}(\psi_f) \right] \\ & + \sum_{h=L,R} \left[(1-b_h) I_c^h(\mathsf{t},\mathsf{b};p) + b_h I_b^h(\mathsf{t},\mathsf{b};p) + 2\lambda_h I_\lambda^h(\mathsf{t},\mathsf{b};p) \right] \\ & - I_{mass}(\mathsf{t},\mathsf{b})\end{aligned}$$

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top-bottom quark sector of BESS

$$\mathcal{L}_f^{(\mathsf{t},\mathsf{b})}=\sum_{h=L,R}\left[\frac{1}{1+\tilde{b}_h}I_c^h+\frac{\tilde{b}_h}{1+\tilde{b}_h}I_b^h+\frac{\tilde{\lambda}_h}{1+\tilde{b}_h}I_\lambda^h\right]_{p=1}-I_{mass}(\mathsf{t},\mathsf{b})$$

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Top-BESS at low-energy

Low-energy top-BESS Lagrangian $\mathcal{L}^{LE}_{tBESS}$

integrate ρ out:

- $M_\rho = \sqrt{\alpha} g'' v/2 \;\; \rightarrow \;\; \infty$ while g'' fixed and finite
- substitute ρ from its LE-EofM: $\rho = \rho(\mathrm{W,B}) \quad \Rightarrow \quad \mathcal{L}^{LE}_{tBESS}$

low-energy limits on top-BESS parameters

confront $\mathcal{L}^{LE}_{tBESS}$ predictions with existing measurements

Methods and measurements

1. **ϵ analysis for elweak precision data** $(\epsilon_1, \epsilon_2, \epsilon_3, \epsilon_b)$
   sources: A_{FB}^{ℓ}, $\Gamma(Z \to \ell\ell)$, $\Gamma(Z \to bb)$, M_W/M_Z
   limits: g'', $b_L - 2\lambda_L$ and $b_R + 2\lambda_R$

2. **measurement of B $\to$ $X_s\gamma$** (CLEO, BELLE, BaBar)
   limits: $b_L - 2\lambda_L$ and $b_R + 2\lambda_R$

3. **anomalous WWZ vertex in $p\bar{p} \to$ WZX** (D0)
   limits: g''

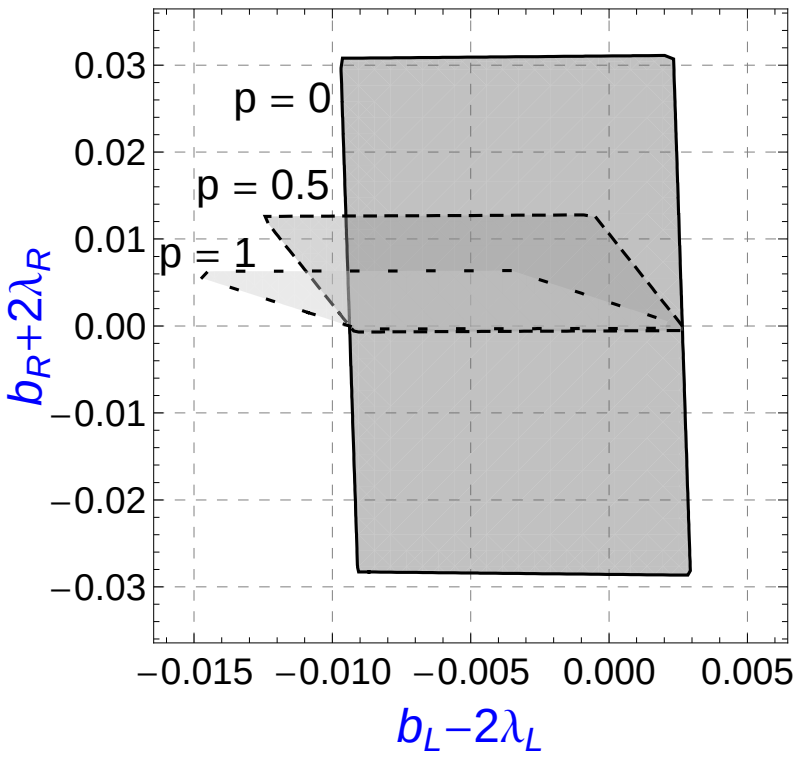
Low-energy limits on Top-BESS parameters

methods 1 + 3:

$$g'' \geq 8$$

methods 1 + 2:

$g'' = 10, \quad \Lambda_{LE} = 1$ TeV $(\leq M_\rho)$



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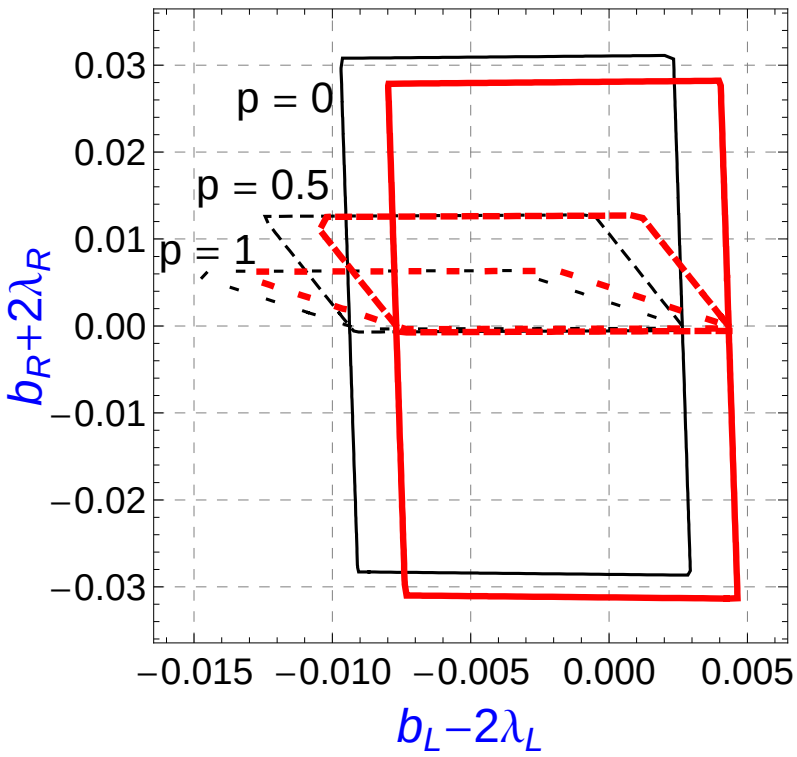

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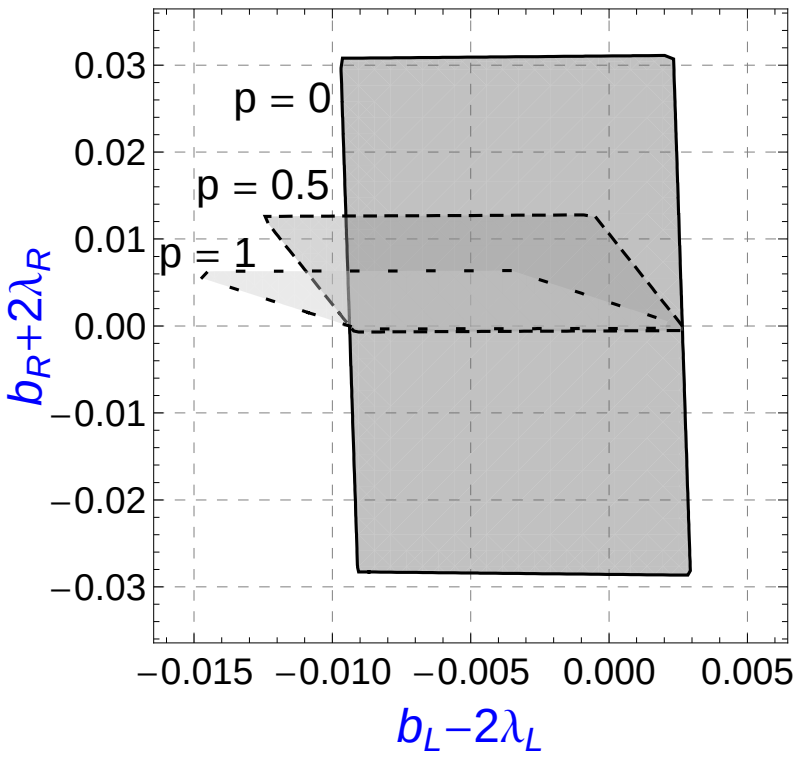

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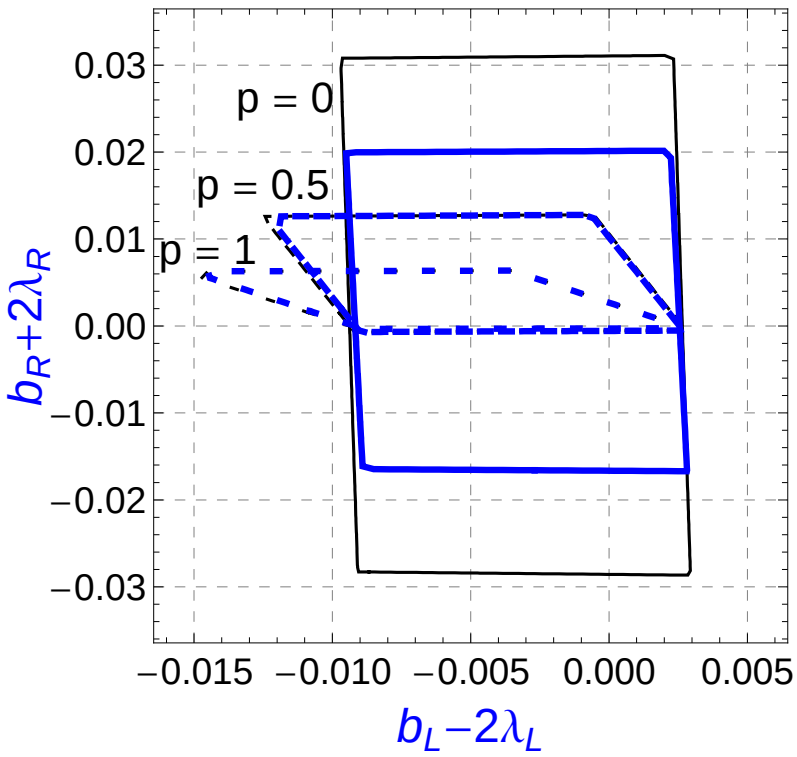

Unitarity limits

considered amplitudes:

- $W_L^+ W_L^- \to W_L^+ W_L^-$
- $W_L^+ W_L^- \to t\bar{t}$
- $t\bar{t} \to t\bar{t}$
- $t\bar{b} \to t\bar{b}$

$\Lambda_{tBESS} = 2.5$ TeV $\quad \Rightarrow \quad$ weaker restrictions than LE limits

Conclusions

This work is a part of the ongoing study of the top-BESS model.

- effective description of LE limits of BSM theories (ESB mechanism)
- parameterization of expected signals from LHC
- ILC processes — see presentation by B. Trpišová