top-BESS Model and its Phenomenology

M. Gintner [1,2], *J. Juráň* [2], *I. Melo* [1]

[1] Žilina U.

[2] IEAP CTU Prague

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Outline

1. Introduction
2. top-BESS Model
3. Phenomenology

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1 Introduction

2 top-BESS Model

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EW symmetry broken!

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$$\mathcal{L}_{SSB} = ?$$

Higgs boson alternatives

heavy/no Higgs violates unitarity $\approx$ 1 TeV ... new particles/forces

weakly interacting:

- *perturbative*

strongly interacting:

- *non-perturbative* $\rightarrow$ *bound states*

extra-dimensions:

5D *weakly* interacting $\longleftrightarrow$ 4D *strongly* interacting

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Effective description of Strong ESB

$SU(2)_L \times U(1)_Y$ broken *dynamically*:

- *not* solvable perturbatively
- *chiral effective* Lagrangian for Goldstone bosons

$$\mathcal{L} = \frac{v^2}{2} \mathrm{Tr}\left[(\partial_\mu U^\dagger)(\partial^\mu U)\right]$$

nonlinear sigma model

$$U = \exp(2i\pi^a \tau^a / v)$$

- ... + resonances

scalar, vector, ...

LHC $\rightarrow$ the *lightest* BSM resonances

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BESS model

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PL**B155**, 95 (1985), NP**B282**, 235 (1987)

- Higgsless ESB sector ... *3 Goldstone bosons*
- new strong physics ... *new vector resonances*
- effective Lagrangian

$$\mathcal{L}_{BESS} = \mathcal{L}_{GB}(W, B, V) + \mathcal{L}_{ESB}(\vec{\pi}, \vec{\sigma}) + \mathcal{L}_{ferm}$$

... *Hidden Local Symmetry*

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BESS symmetries and couplings

- *global symmetry:*

$$SU(2)_L \times SU(2)_R \times U(1)_{B-L} \times SU(2)_{HLS} \xrightarrow{SSB} SU(2)_{L+R} \times U(1)_{B-L}$$

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$$W^{\pm}, Z \quad A \quad V^{\pm}, V^0 \qquad \text{...mixing}$$

- *fermion sector:*
  - direct cplg: ... $bg''\bar{\psi}_L \not{V} \psi_L,\ b'g''\bar{\psi}_R \not{V} \psi_R$ ... **universal**
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Outstanding Top Quark

$m_t \approx v/\sqrt{2}$ $\rightarrow$ special role in ESB?

new physics behind m_t

ESB related

Extended TC, ...

ESB *un*related

Topcolor Assisted TC, ...

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Phys. Rev. **D84**, 035013 (2011)

- *gauge sector* $\equiv$ *BESS*
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  - 3^{rd} quark generation only ... b_L, b_R
  - $bottom_R$ vs. top_R ... p
  - new fermion terms ... λ_L, λ_R

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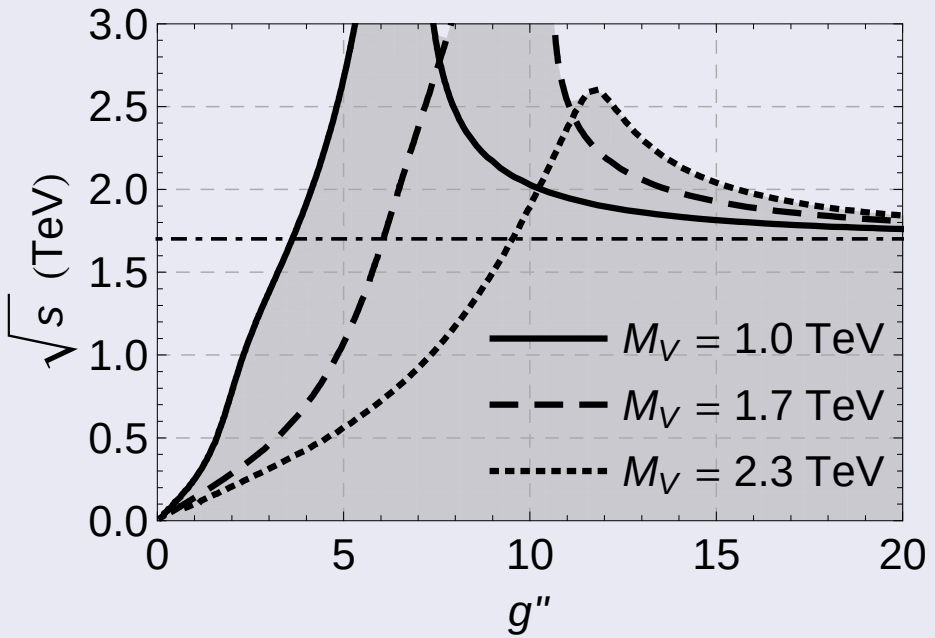
Unitarity constraints

- GB scatterings:
  $W_L^+ W_L^-$, $Z_L Z_L$,
  $W_L^\pm Z_L$, $W_L^\pm W_L^\pm$
- tree level
- Equivalence Theorem



Low-energy limits

experiment: LEP + SLC + Tevatron

EWPD ϵ-analysis: ϵ_1, ϵ_2, ϵ_3, ϵ_b, $\Gamma(Z \to b\bar{b})$, $B \to X_s\gamma$, $p\bar{p} \to WZX$

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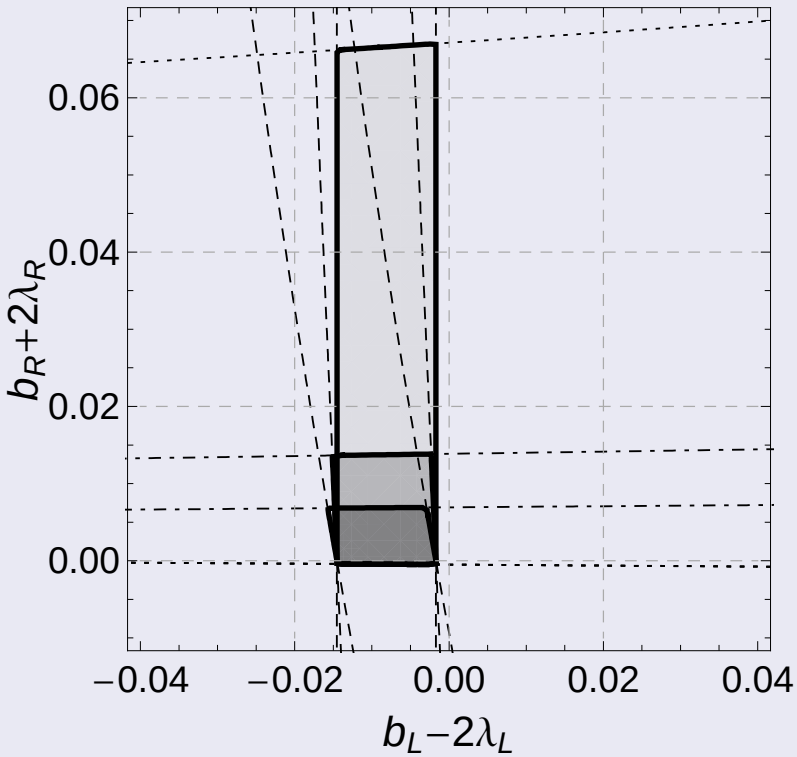

Intersections of 90% C.L. allowed regions.

$M_V = 1$ TeV
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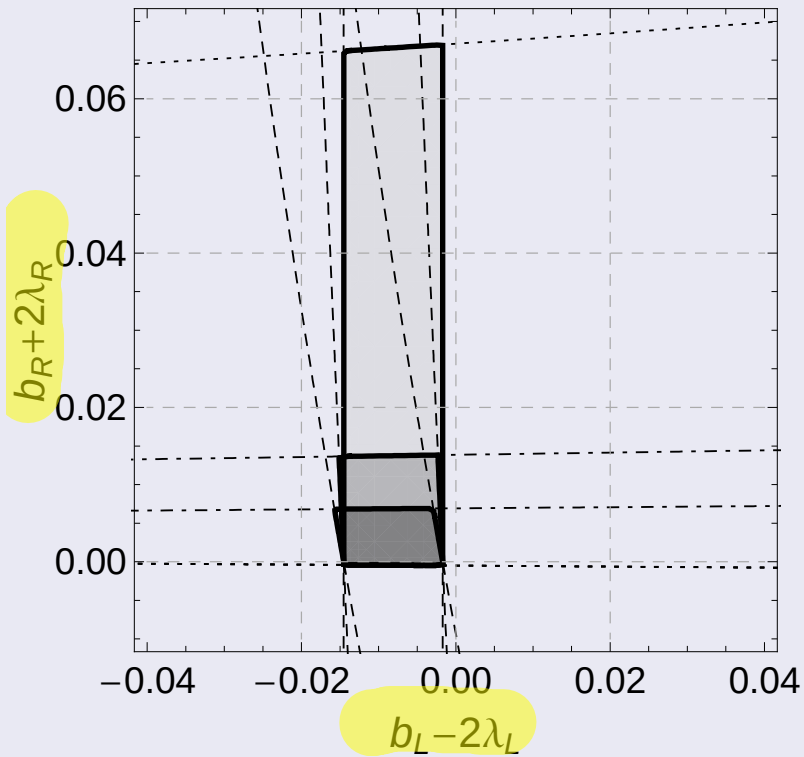

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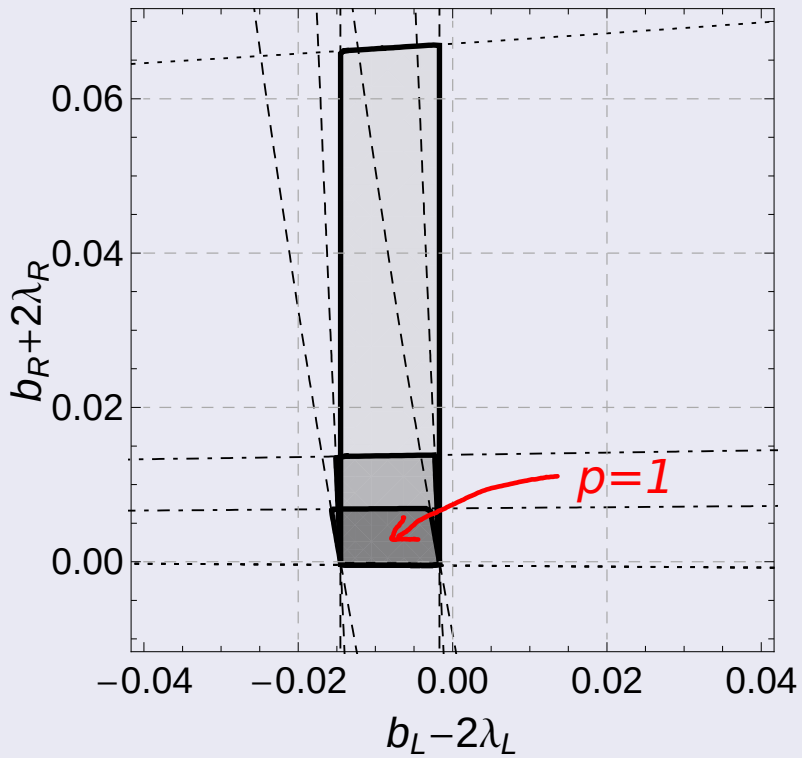

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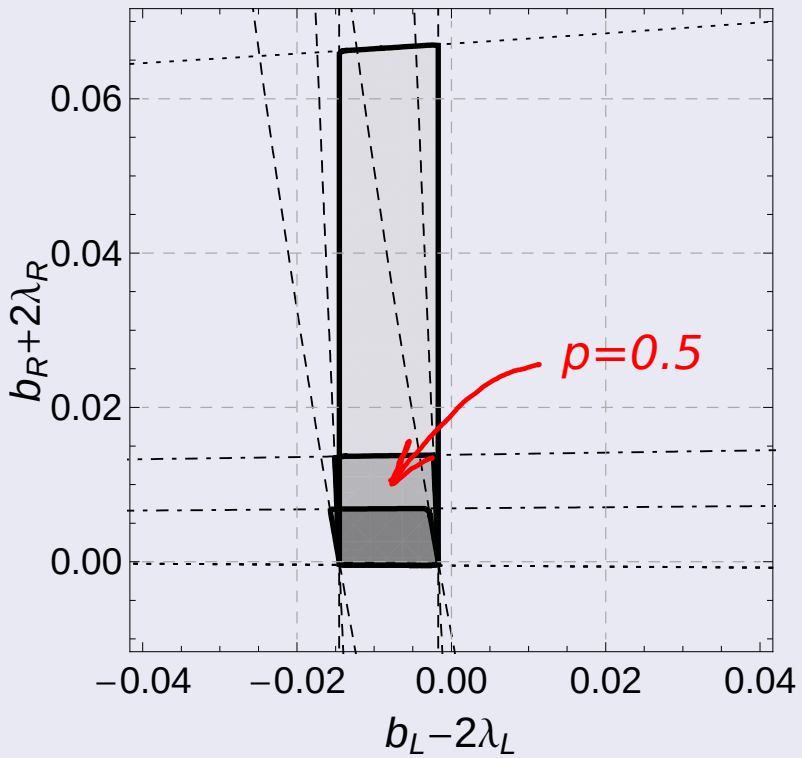

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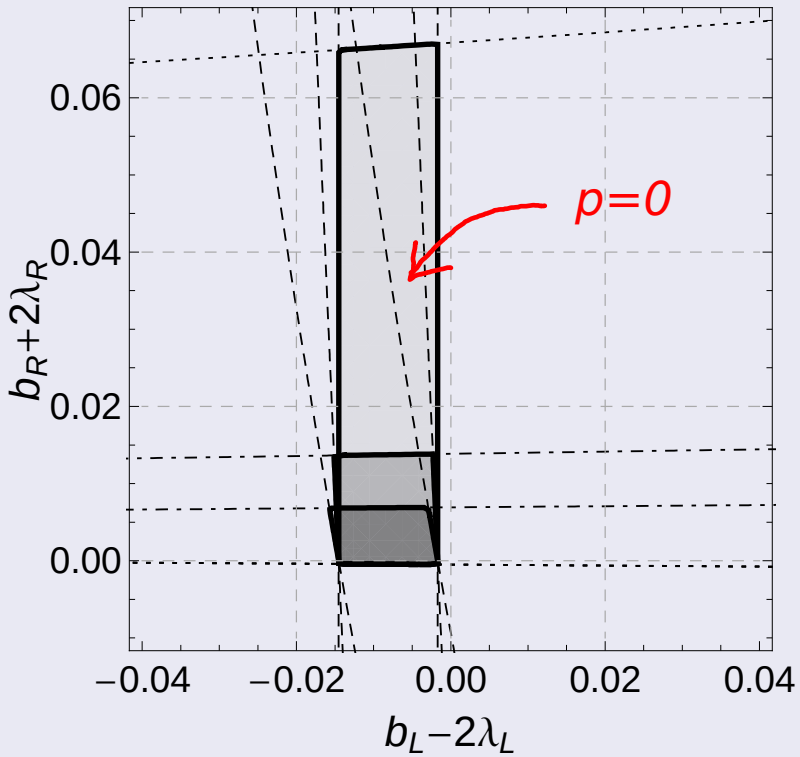

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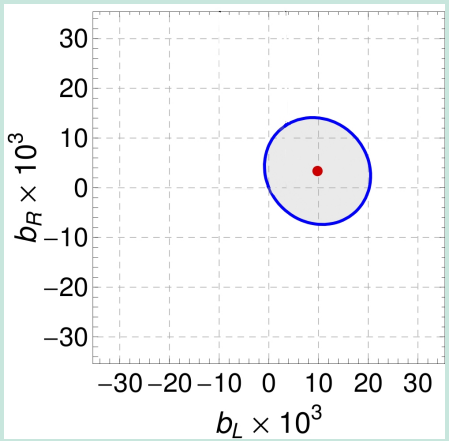

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The Death Valley regions of the $V \to t\bar{t}/b\bar{b}/tb$ *decays.*

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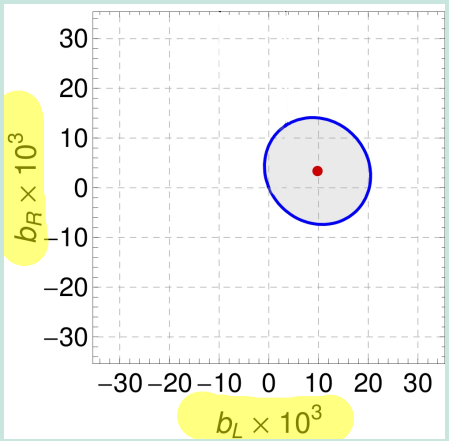

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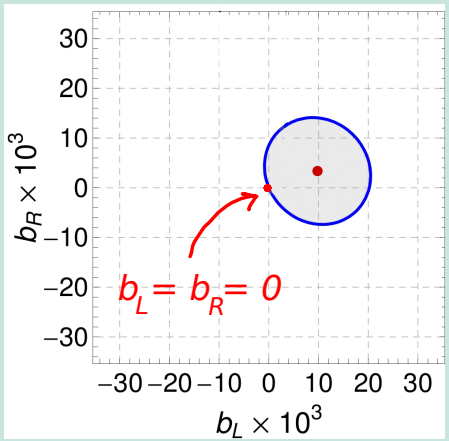

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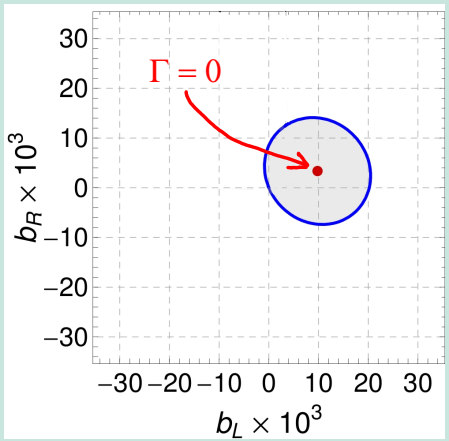

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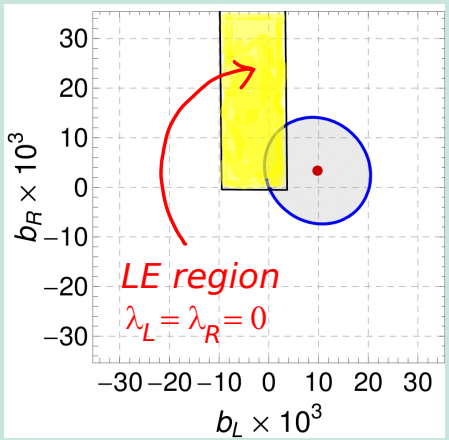

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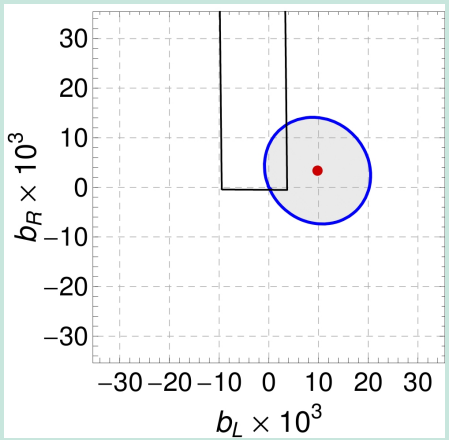

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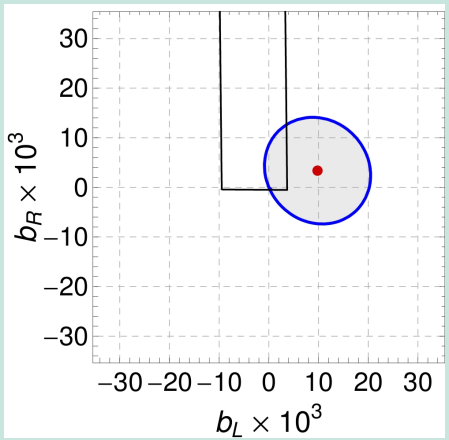

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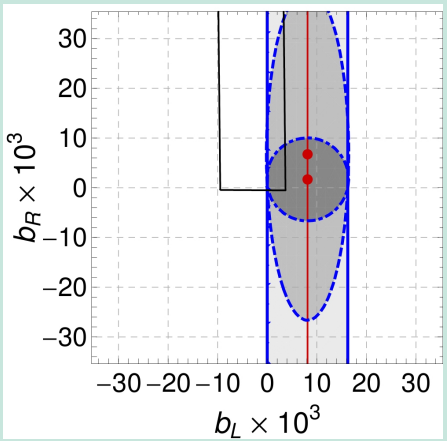
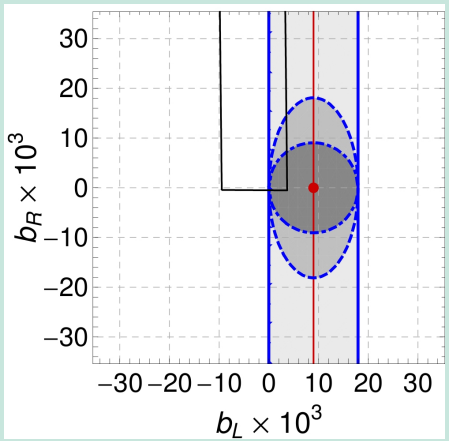


$V^{\pm} \to t\bar{b}/\bar{t}b$



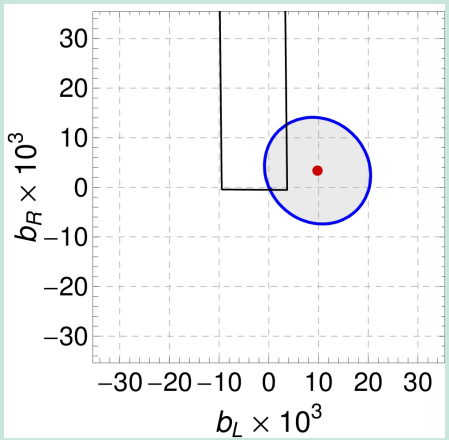
$g'' = 10$

The Death Valley regions of the $V \to t\bar{t}/b\bar{b}/tb$ *decays.*

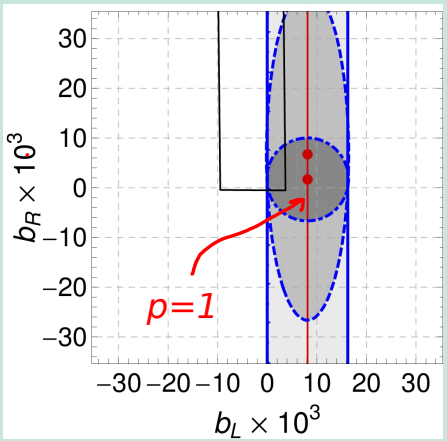
The Death Valley

direct + indirect *cplgs* $\Rightarrow$ *DV*

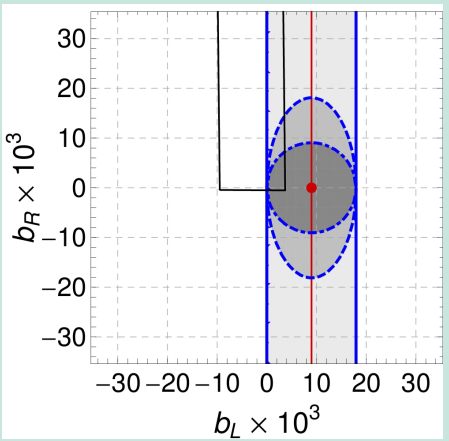
$V^0 \to t\bar{t}$



$V^0 \to b\bar{b}$



$V^{\pm} \to t\bar{b}/\bar{t}b$



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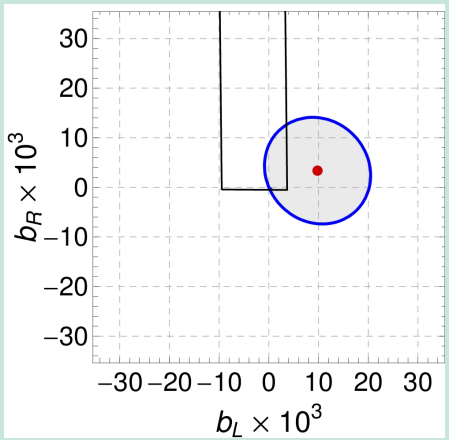
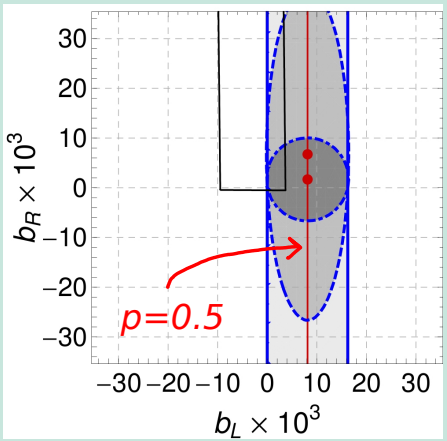


$V^0 \to b\bar{b}$



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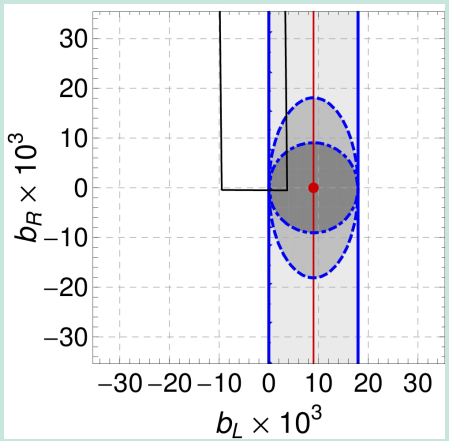

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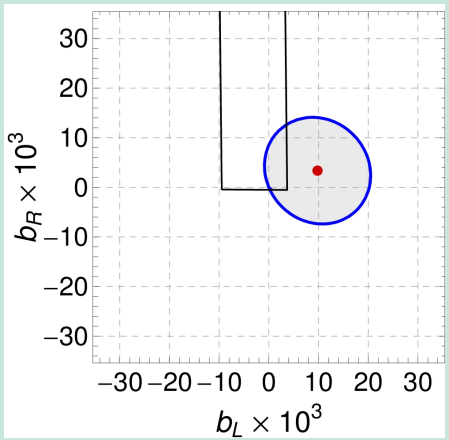

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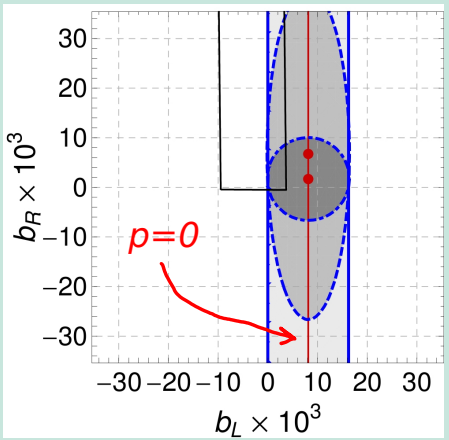
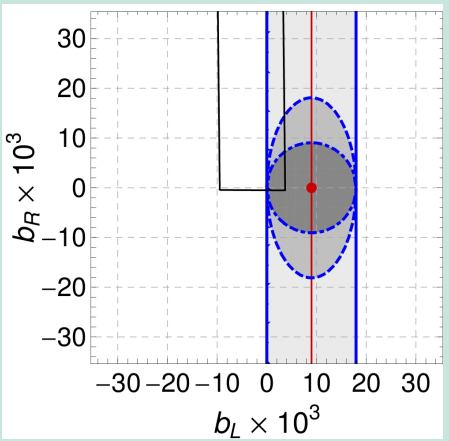


$V^{\pm} \to t\bar{b}/\bar{t}b$



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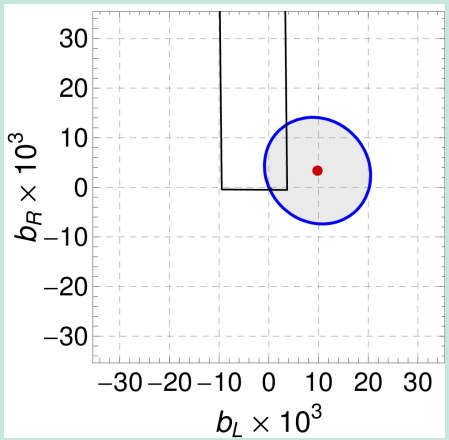

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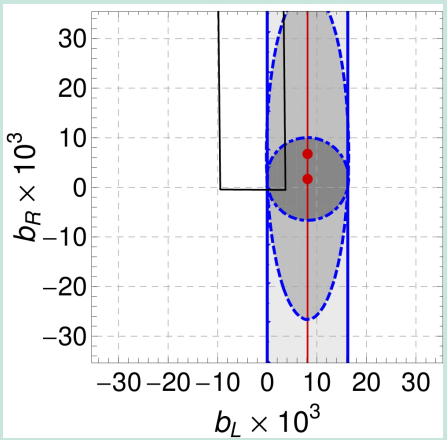

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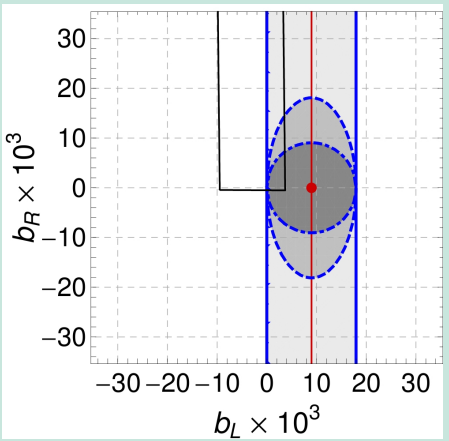

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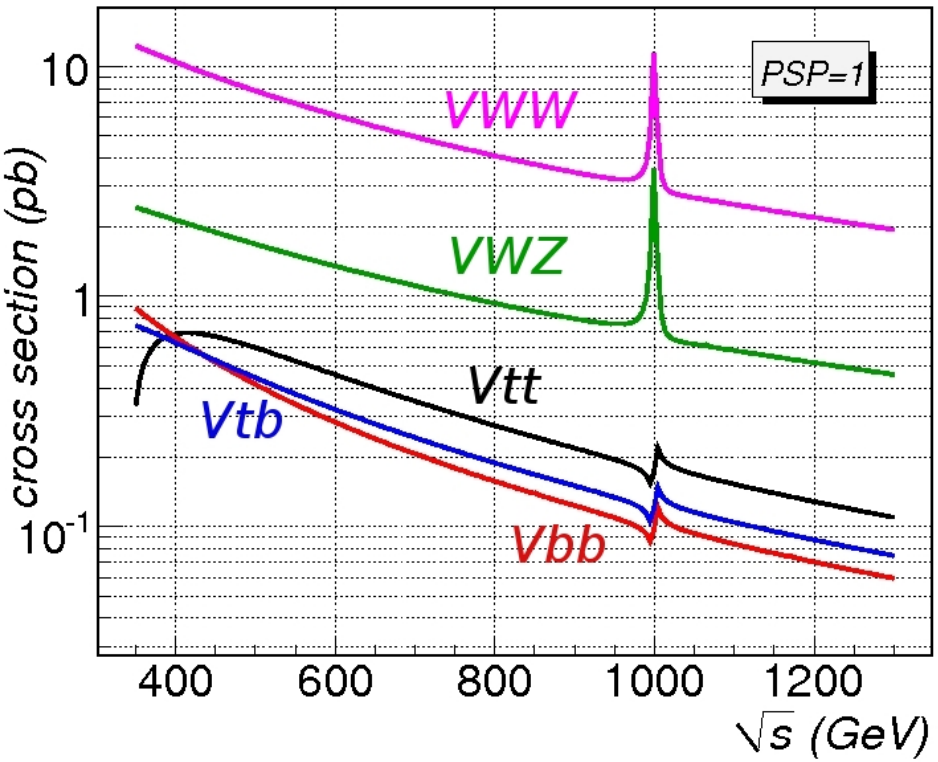
Hiding the peak

$$M_V = 1 \text{ TeV}, \quad g'' = 20, \quad p = 0, \quad \lambda_R = 0$$



- **no direct cplng**
  $b_L = 0$
  $b_R = 0$
  $\lambda_L = 0$
- **outside the DV**
  $b_L = -0.010$
  $b_R = +0.030$
  $\lambda_L = 0$
- **$t\bar{b}$ & $b\bar{b}$ in the DV**
  $b_L = +0.009$
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  $b_L = +0.0098$
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$e^+e^- \to W^+W^-$ $\quad u\bar{d} \to W^+Z$ $\quad e^+e^- \to t\bar{t}$ $\quad u\bar{d} \to t\bar{b}$ $\quad e^+e^- \to b\bar{b}$

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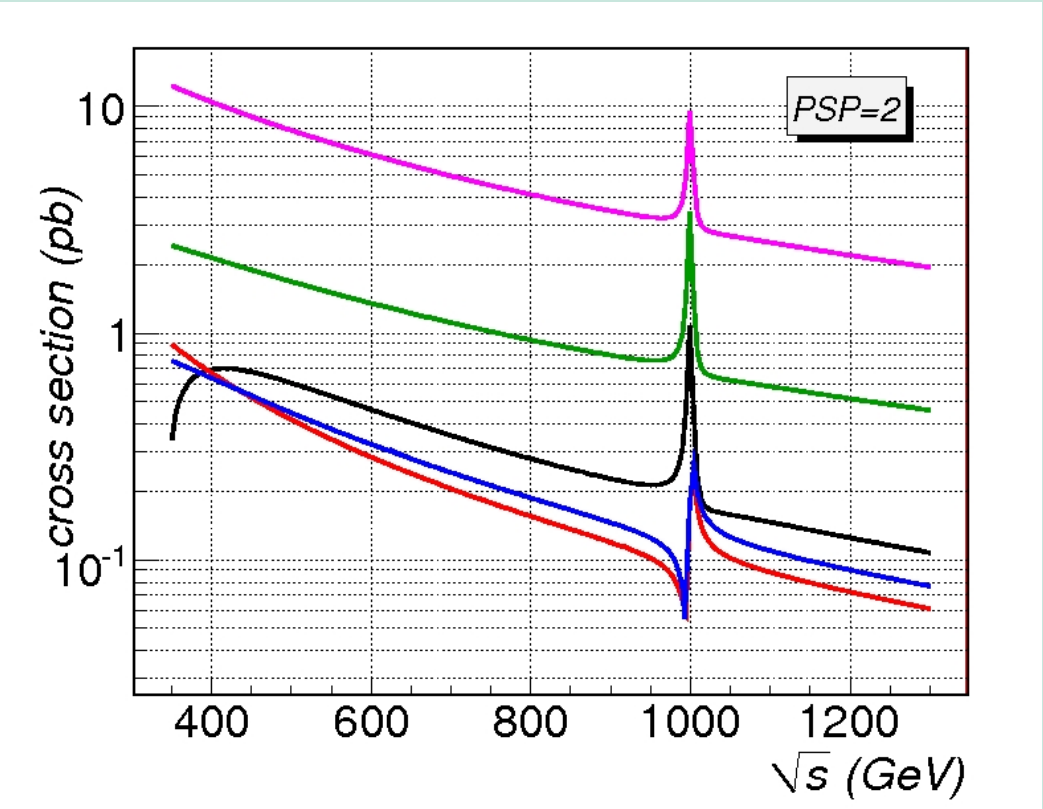

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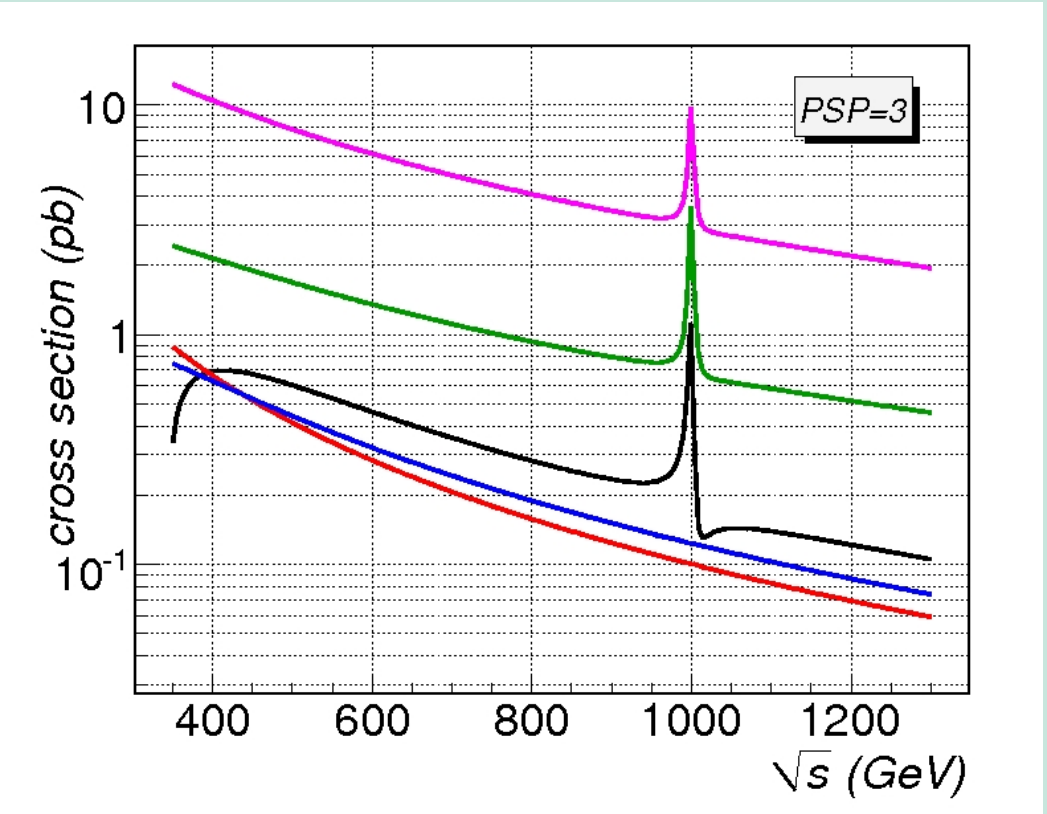

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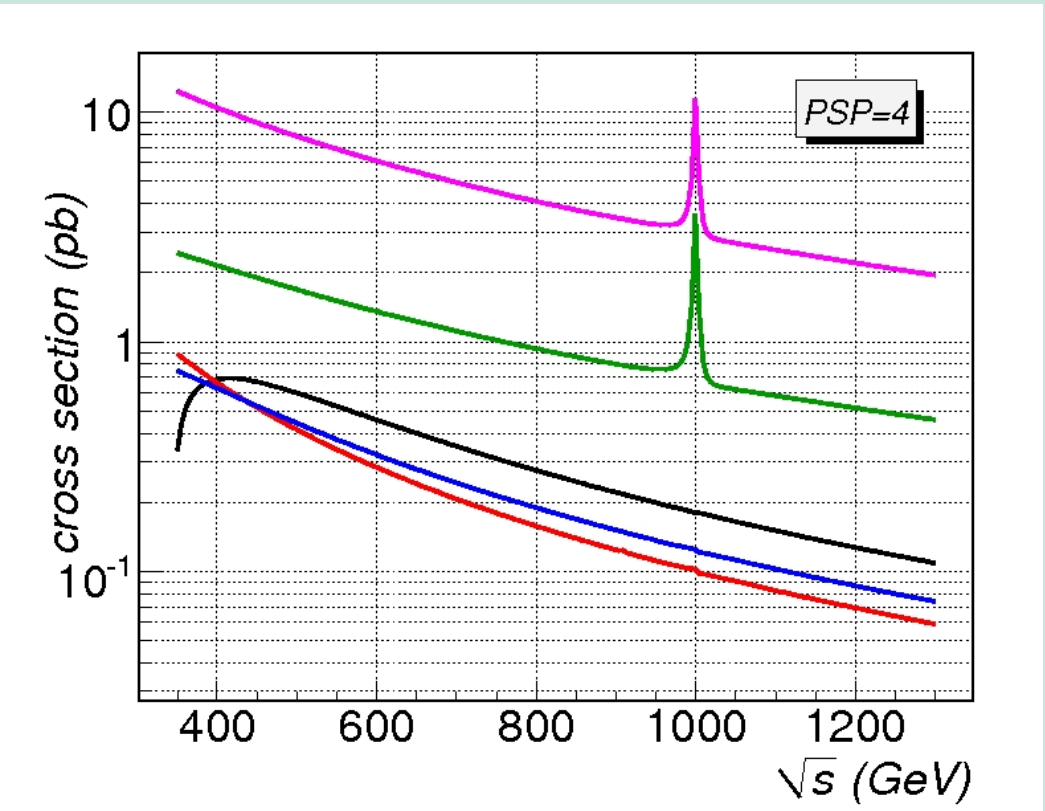

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Conclusions

- effective description of strong ESB new physics needed
- top-BESS — modification of BESS, special role of top quark
  - *new SU(2) resonance triplet*
  - *direct coupling to top and bottom*
  - *λ-terms*
- low-E limits on the fermion parameters relaxed
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ACKNOWLEDGMENTS

- Research Program MSM6840770029
- Project International Cooperation ATLAS-CERN of the Ministry of Education, Youth and Sports of the Czech Republic

Top-BESS: new couplings

HLS vector triplet couplings:

- $SU(2)_{HLS}$ gauge coupling ... g''
- $V^0 t_L t_L$, $V^\pm t_L b_L$, $V^0 b_L b_L$ ... $b_L \cdot g''$
- $V^0 t_R t_R$ ... $b_R \cdot g''$
- $V^\pm t_R b_R$ ... $p \cdot b_R \cdot g''$, $0 \leq p \leq 1$
- $V^0 b_R b_R$ ... $p^2 \cdot b_R \cdot g''$

2 *lambda* terms ... λ_L, λ_R

- *negligible at V-peak*
- *modify interaction of fermions with EW gauge bosons*