top-BESS Model and its Phenomenology

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

[1] Žilina U.

[2] IEAP CTU in Prague

Phys. Rev. D **84**, 035013 (2011)

Theoretical Physics Workshop and Summer School

Svit, September 9, 2011

Outline

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Electroweak symmetry

Standard model — Gauge Principle

$$SU(2)_L \times U(1)_Y \quad \Rightarrow \quad \text{EW interactions}$$

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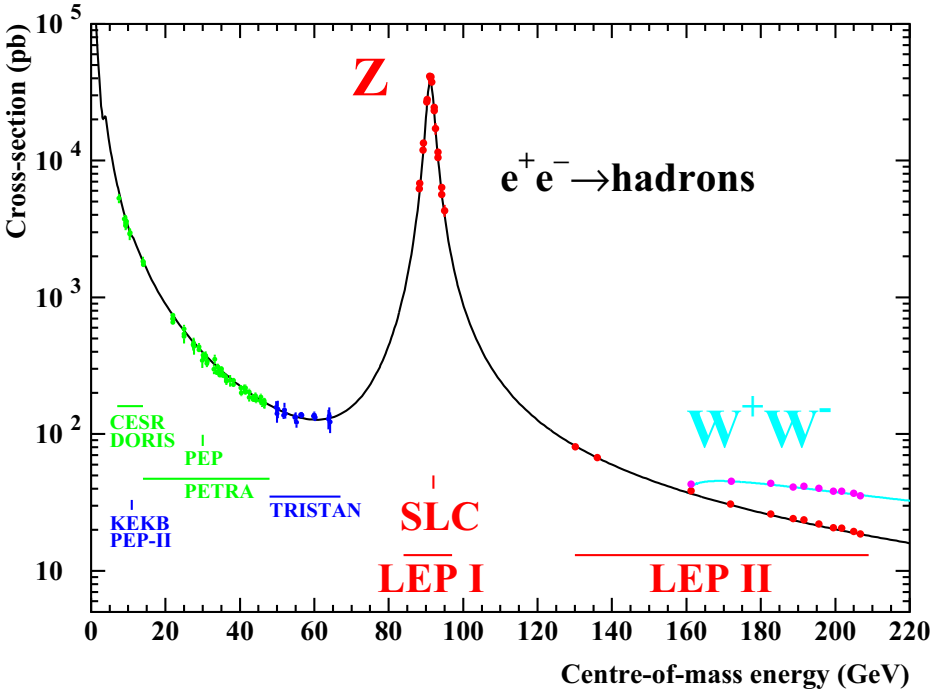

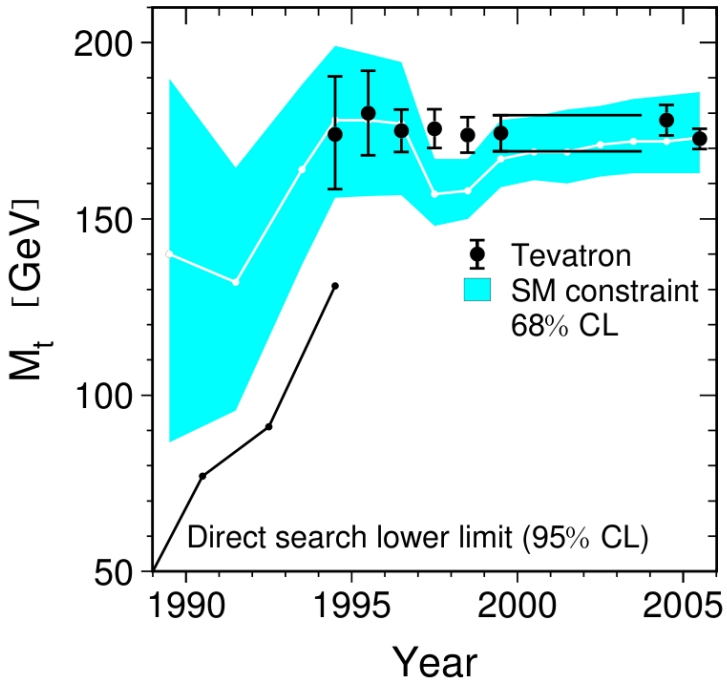

Electroweak symmetry breaking

$$M_W = 80.403 \text{ GeV}$$

$$M_Z = 91.1876 \text{ GeV}$$

Electroweak Symmetry Breaking puzzle

Spontaneous Symmetry Breaking + Higgs mechanism

$$\mathcal{L}_{EW,m=0} \longrightarrow \mathcal{L}_{EW,m=0} + \mathcal{L}_{spont.ESB}$$

the puzzle: $\mathcal{L}_{spont.ESB} = ?$

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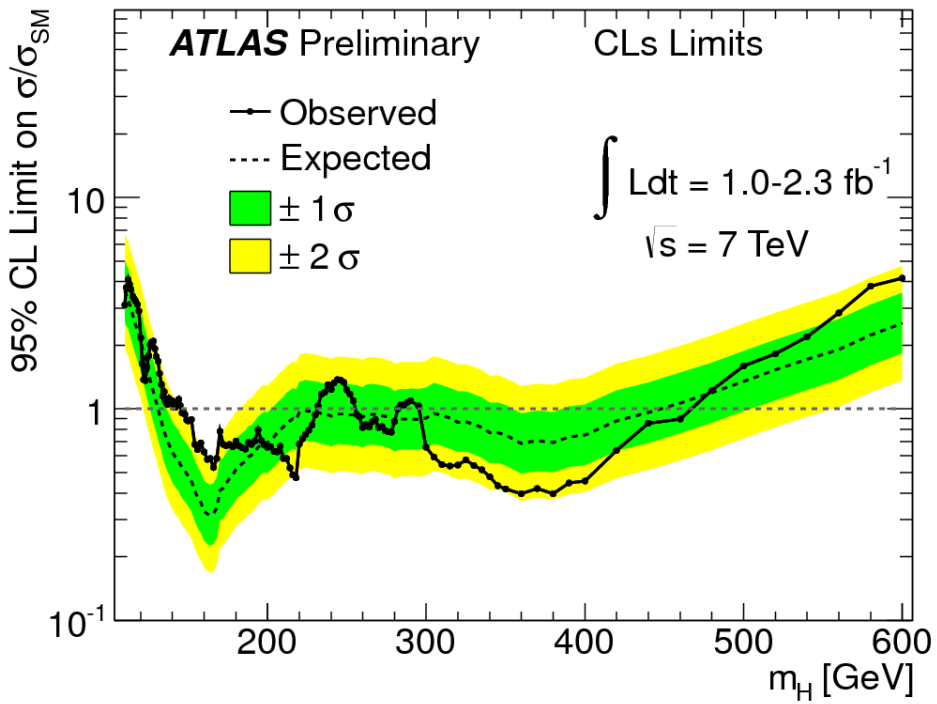
ESB scenarios

Higgs and the others

Benchmark hypothesis $\rightarrow$ **SM Higgs**



ESB alternatives

- Weakly interacting more Higgses, SUSY
- Strongly interacting Technicolor and its extensions

ESB SCENARIOS

HIGGS AND THE OTHERS

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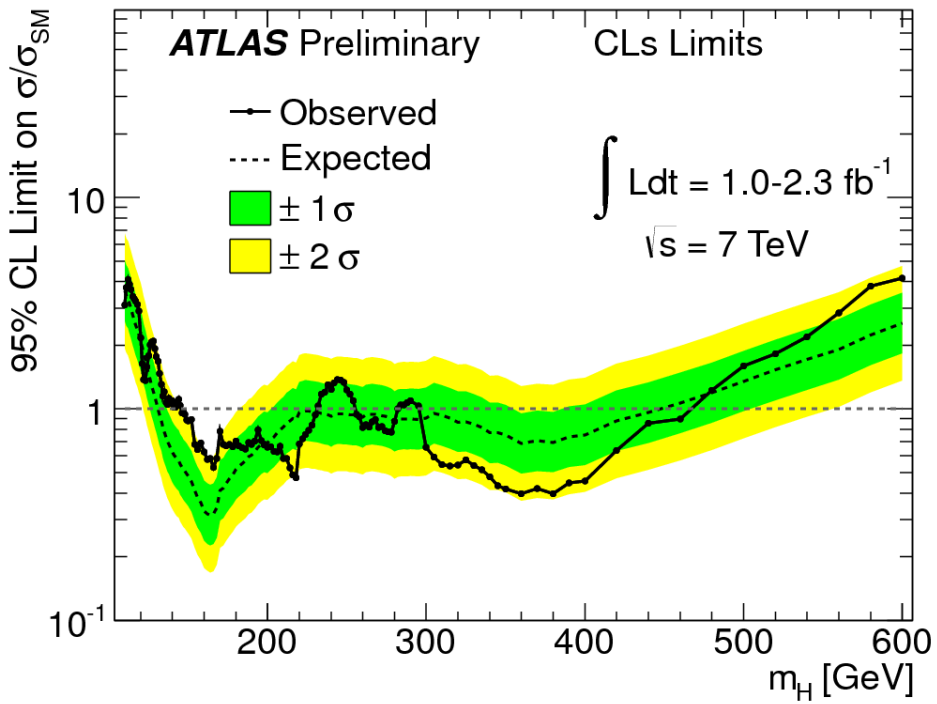

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New particles WANTED!

Model Dependent

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

Model InDependent

heavy/no Higgs violates unitarity ≈ 1 TeV

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Outstanding Top Quark

$m_t \approx v$ $\rightarrow$ special role in ESB?

new physics behind m_t

ESB related

ESB *un*related

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Breaking Electroweak Symmetry Strongly

- effective Lagrangian
- $\not{H}$SM + new vector resonances

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Hidden Local Symmetry

M. Bando, T. Kugo, K. Yamawaki (1984)

Any NLσM(G/H) is *gauge equivalent* to "linear" $G_{glob} \times H_{loc}$ model.

ESB: $G = SU(2)_L \times SU(2)_R$

$H = SU(2)_{L+R}$

BESS Model

Breaking Electroweak Symmetry Strongly

- *global symmetry:*

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

- *local symmetry:*

$$\underset{g}{SU(2)_L} \times \underset{g'}{U(1)_Y} \times \underset{g''}{SU(2)_{HLS}} \xrightarrow{SSB} \underset{e}{U(1)_{em}}$$

- *Gauge sector:* GB-mixing
- *Fermion sector:*
  - ◇ direct coupling: universal chiral ... bg'', $b'g''$
  - ◇ indirect coupling: GB-mixing induced ... $1/g''$

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top-BESS Model

Phys. Rev. D **84**, 035013 (2011)

- *gauge sector:* identical to BESS
- *fermion sector:* **modified**

$$m_t \approx v \;\rightarrow\; \text{special role in ESB?}$$

- 3^{rd} quark generation singled out ... b_L, b_R
- $bottom_R$ disentangled from top_R ... p
- new fermion Lagrangian terms ... λ_L, λ_R

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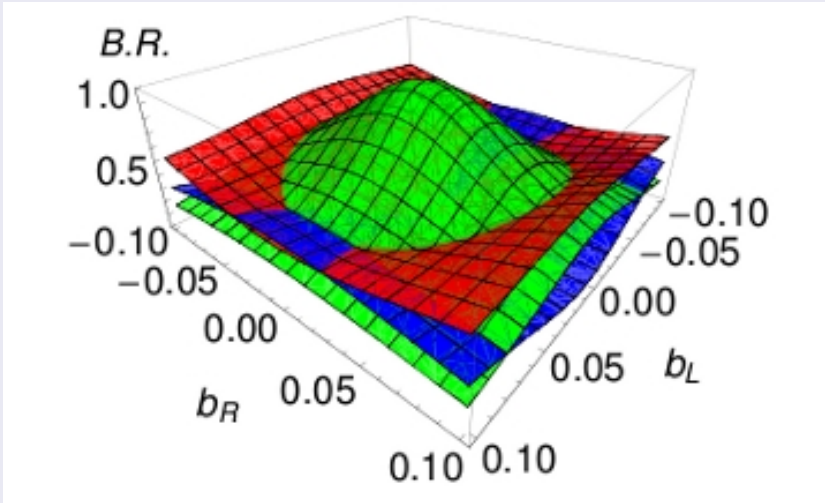
Outline

Phenomenology

Decay Widths

- $V \to (W, Z) + (t, b) + ...$
- $\Gamma \sim 10$ GeV

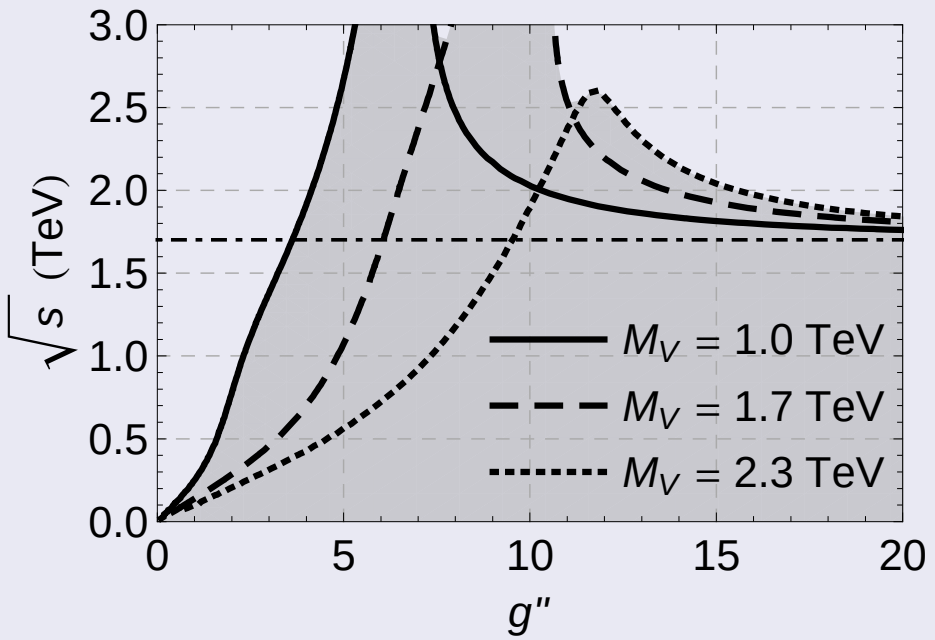


WW, *tt*, *bb*

Phenomenology

Unitarity constraints

- $W_L^+W_L^-$, Z_LZ_L, $W_L^\pm Z_L$, $W_L^\pm W_L^\pm$
- tree level
- Equivalence Theorem



Low-energy limits

Measured Observables (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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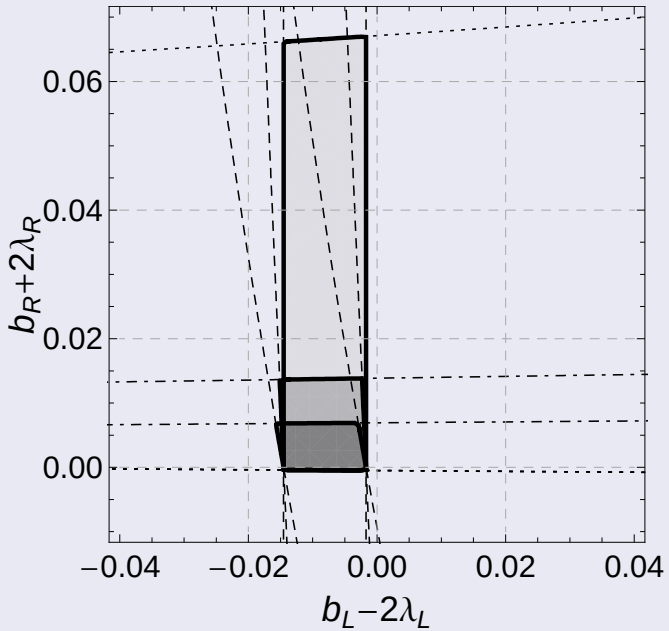
ϵ_1, $\Gamma(Z \to b\bar{b})$, $B \to X_s\gamma$ restriction



Intersections of 90% C.L. allowed regions.

$M_V = 1$ TeV
$g'' = 10$

The Death Valley

direct + indirect *couplings* $\Rightarrow$ DV

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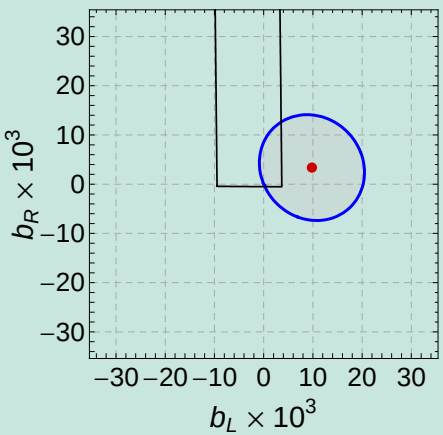
direct + indirect *couplings* $\Rightarrow$ *DV*

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



$g'' = 10,\ \lambda_L = \lambda_R = 0$

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

The Death Valley

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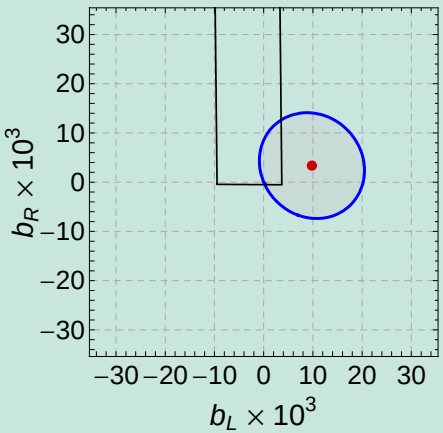

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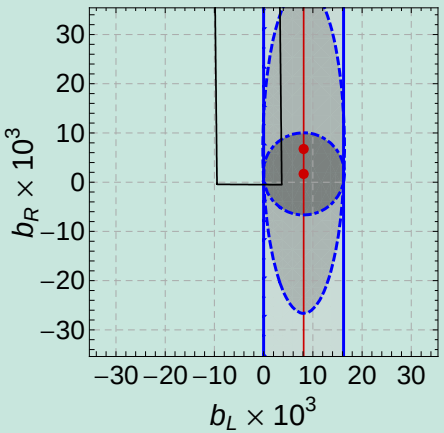
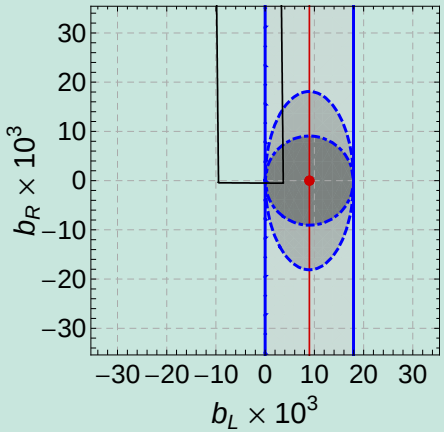


$V^{\pm} \to t\bar{b}/\bar{t}b$



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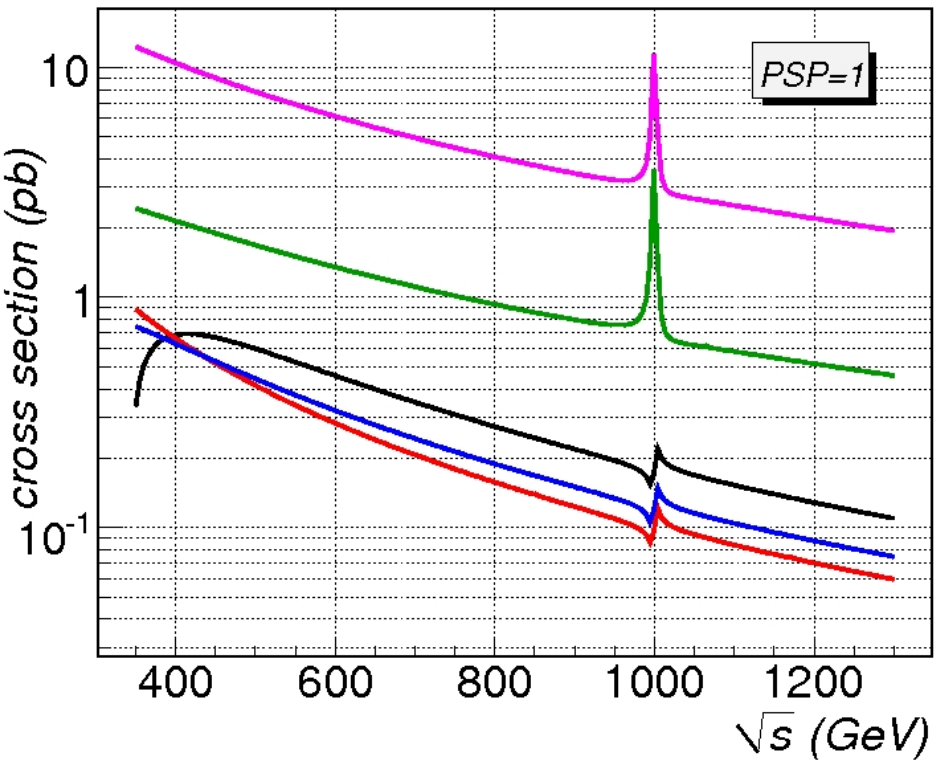
Hiding the peak

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



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- **outside the DV**
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- **$t\bar{b}$ & $b\bar{b}$ in the DV**
  $b_L = +0.009$
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- **all in the DV**
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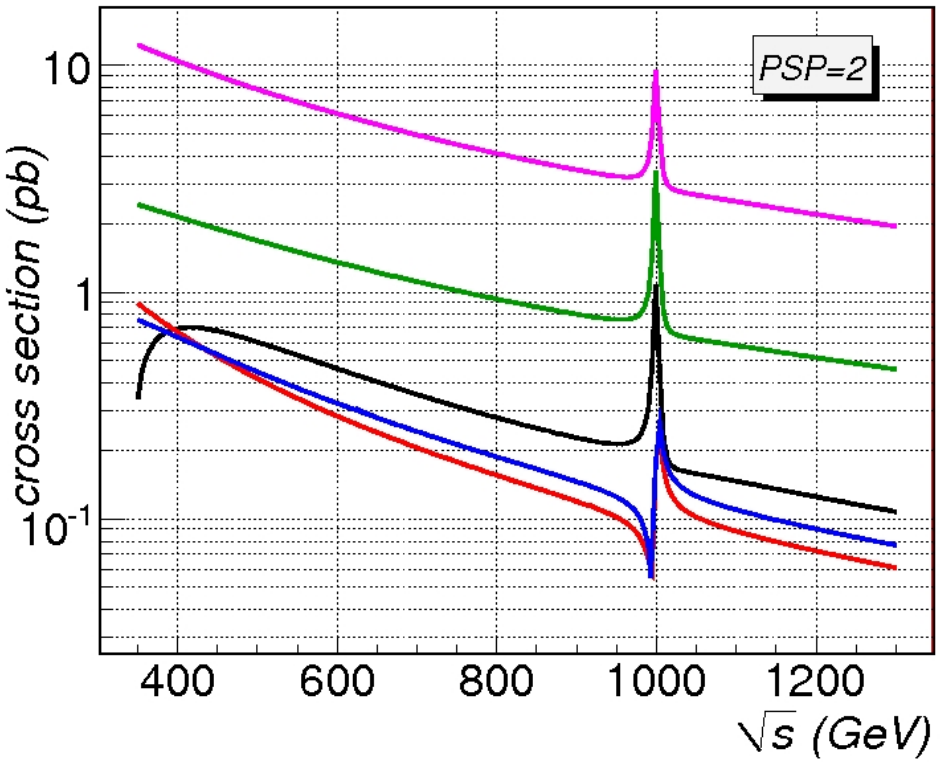

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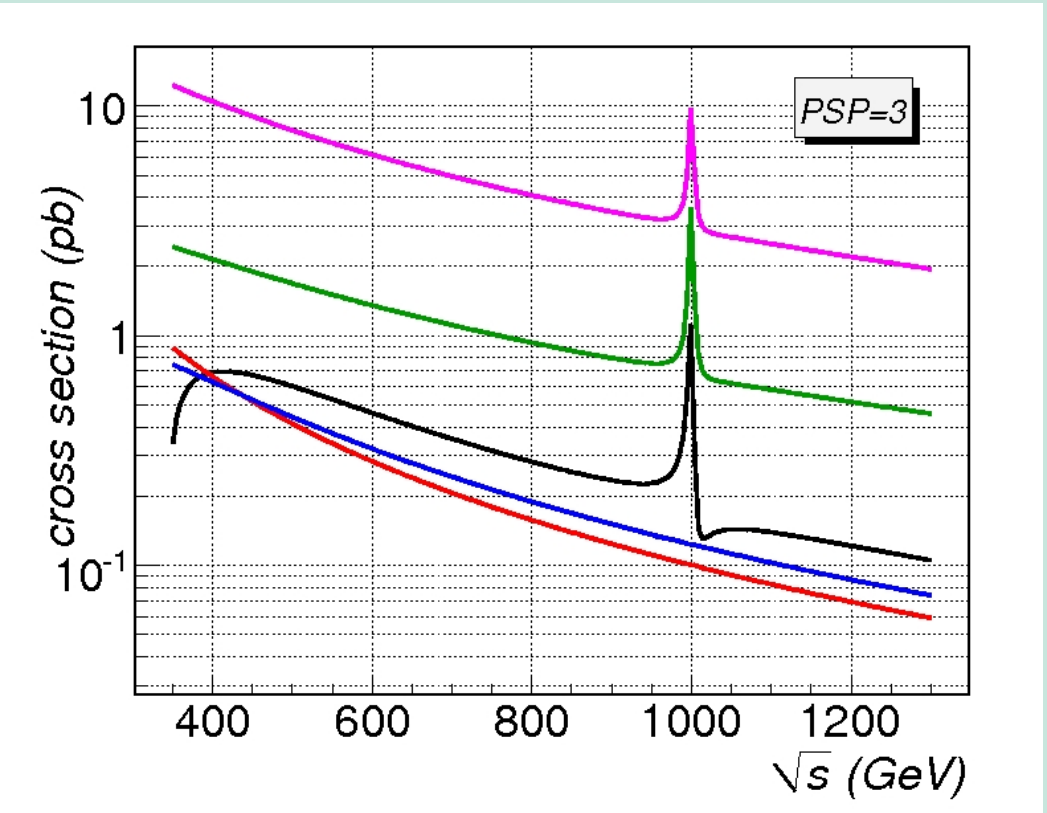

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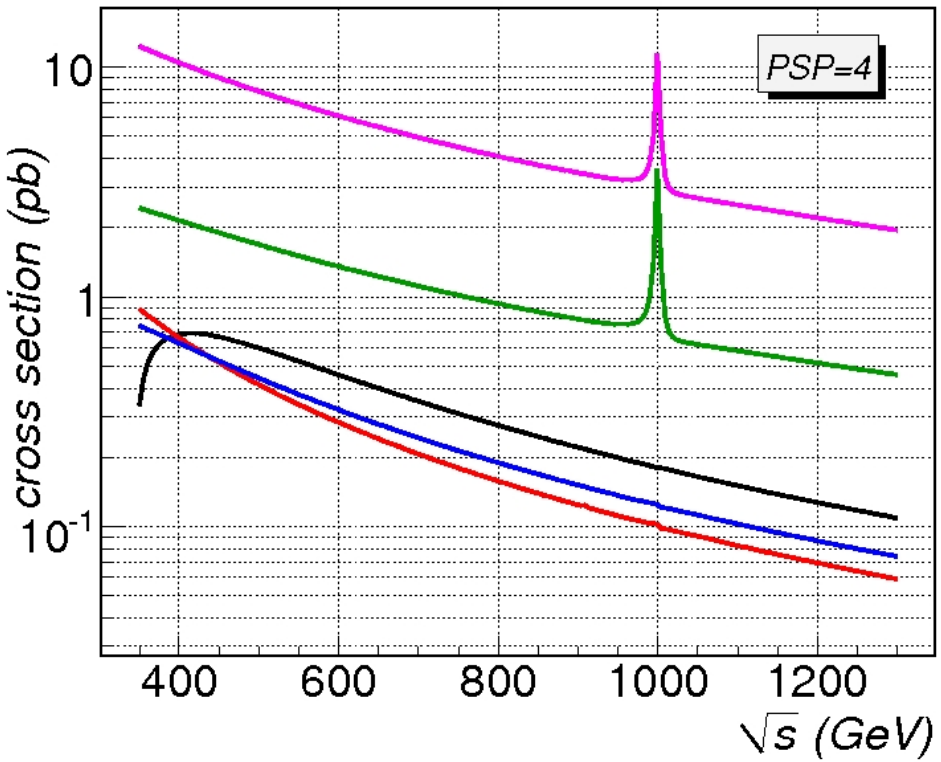

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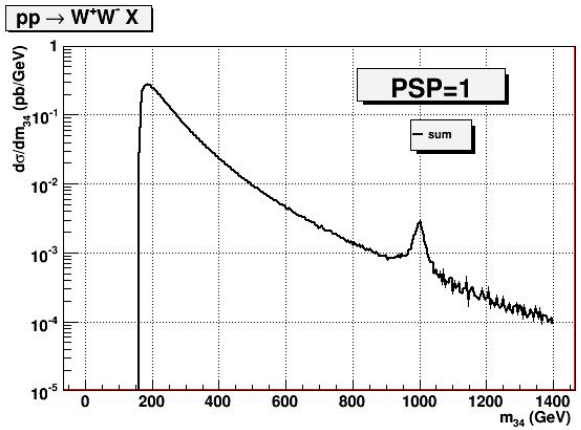
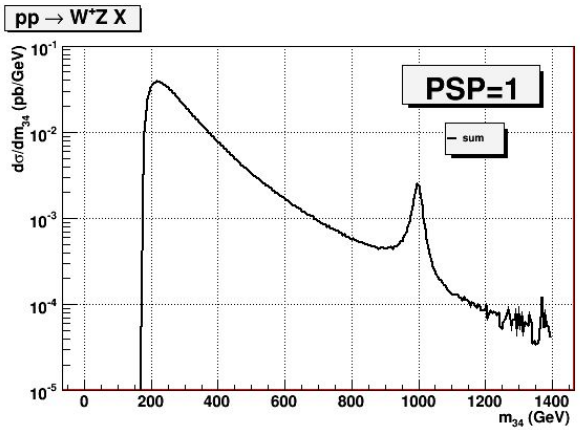
What's next?

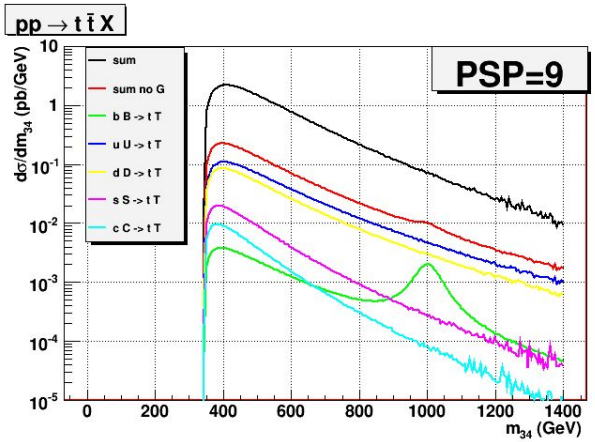
Plans

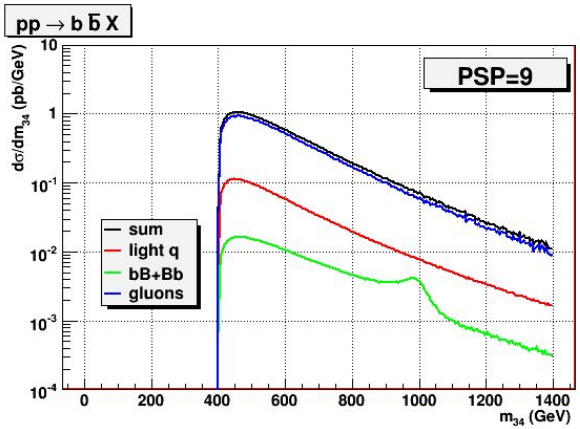
- theoretical development
- Probing top-BESS model at LHC and ILC
- direct vs. indirect couplings
- Drell-Yan processes at LHC

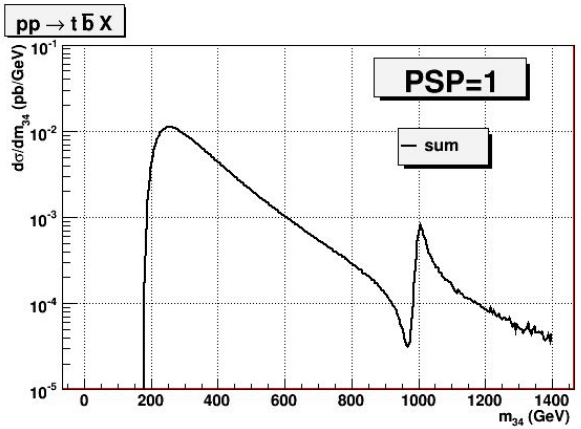
Drell-Yan at LHC











I WANT **YOU** !!!

Enlist Now!

Conclusions

- the actual mechanism of ESB still remains a puzzle
- **top-BESS model** — the effective description of strong ESB
- modification of BESS model; special role of top quark
  - ⋆ *new SU(2) vector triplet*
  - ◇ *direct coupling to top and bottom only*
  - ◇ *disentangled interaction of the right-handed top-bottom doublet*
  - ◇ *new λ terms*
- low-energy limits on the fermion parameters are relaxed
- Physical Review D **84**, 035013 (2011)

Backup

Couplings

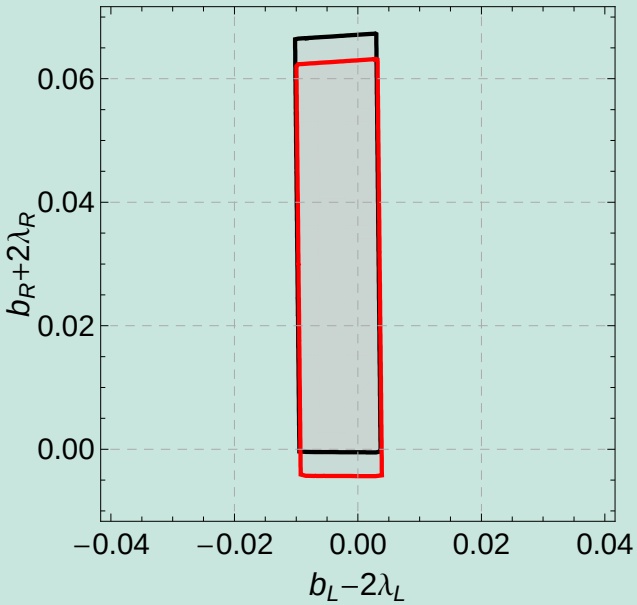
HLS vector triplet couplings to top and bottom quarks

- $V^0 \mathrm{t}_L \mathrm{t}_L$, $V^\pm \mathrm{t}_L \mathrm{b}_L$, $V^0 \mathrm{b}_L \mathrm{b}_L$ ... $b_L \cdot g''$
- $V^0 \mathrm{t}_R \mathrm{t}_R$ ... $b_R \cdot g''$
- $V^\pm \mathrm{t}_R \mathrm{b}_R$ ... $p \cdot b_R \cdot g''$, $0 \leq p \leq 1$
- $V^0 \mathrm{b}_R \mathrm{b}_R$ ... $p^2 \cdot b_R \cdot g''$

Low-energy limits

on fermion parameters

ϵ_1, ϵ_b, $B \to X_s\gamma$



$g'' = 10$
$g'' = \infty$

$\Lambda = 1$ TeV

$p = 0$

The intersections of the 90% C.L. allowed regions.

Low-energy limits

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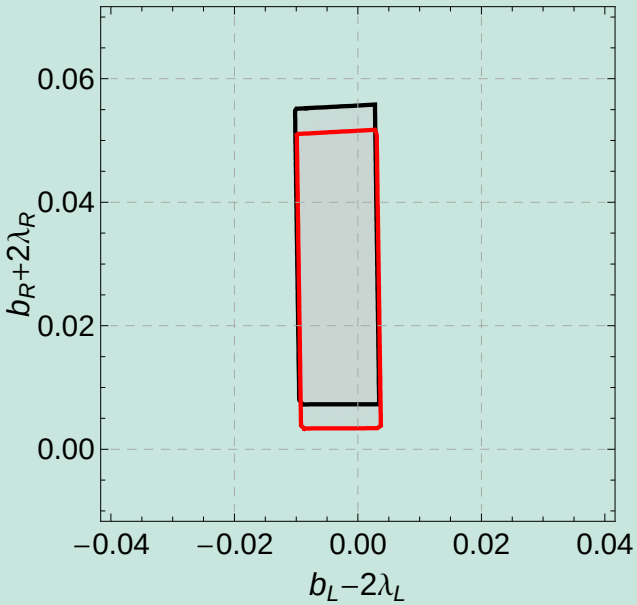

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$\Lambda = 2$ TeV

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ϵ_1, $\Gamma(Z \to b\bar{b})$, $B \to \lambda_{1,2}$

The intersections of the 90% C.L. allowed regions.

fine-tuning $< 10\%$ $\Rightarrow$ $|b_L| \leq 0.13$

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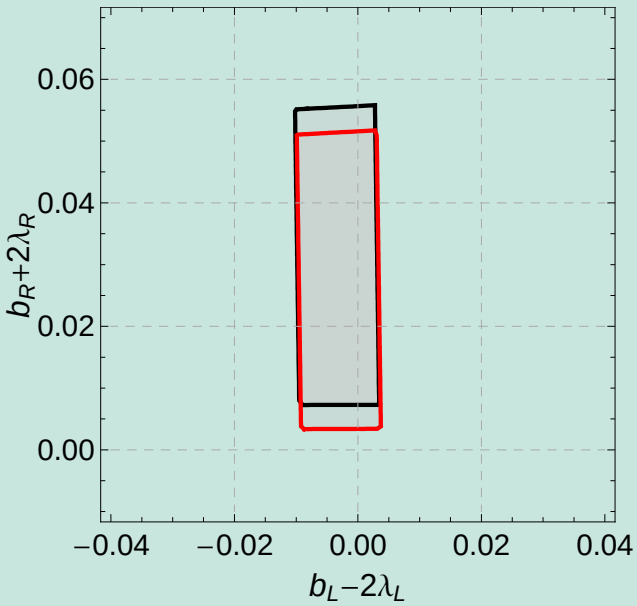

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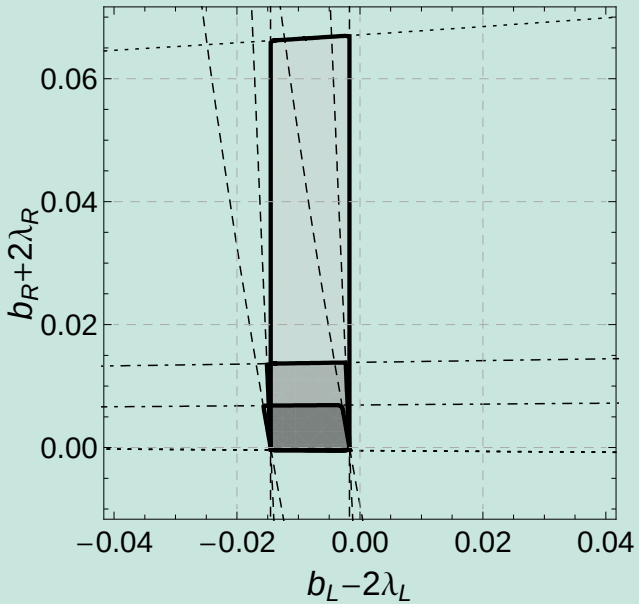

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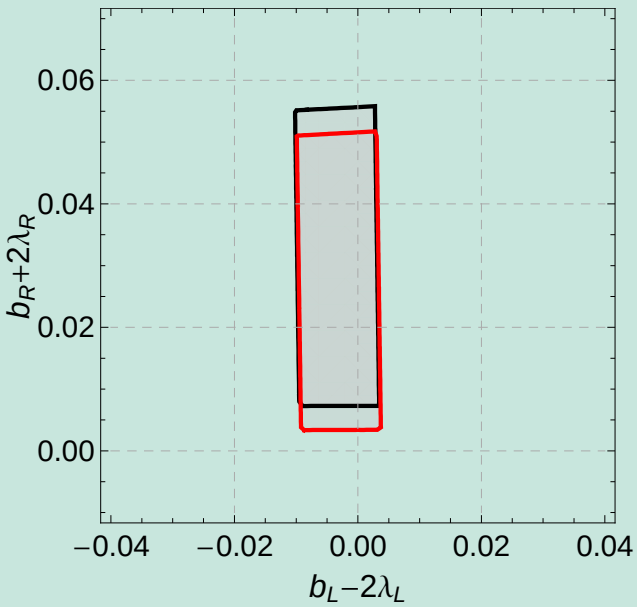
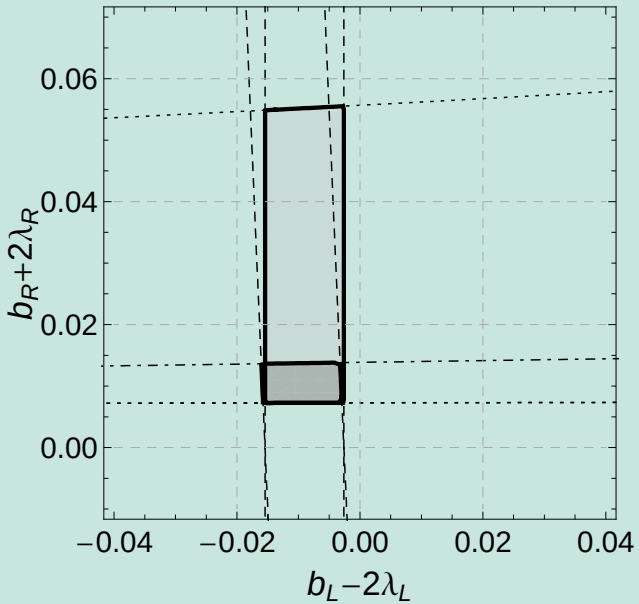


$g'' = 10$
$g'' = \infty$

$\Lambda = 2$ TeV

$p = 0, 0.5$

ϵ_1, $\Gamma(Z \to b\bar{b})$, $B \to X_s\gamma$



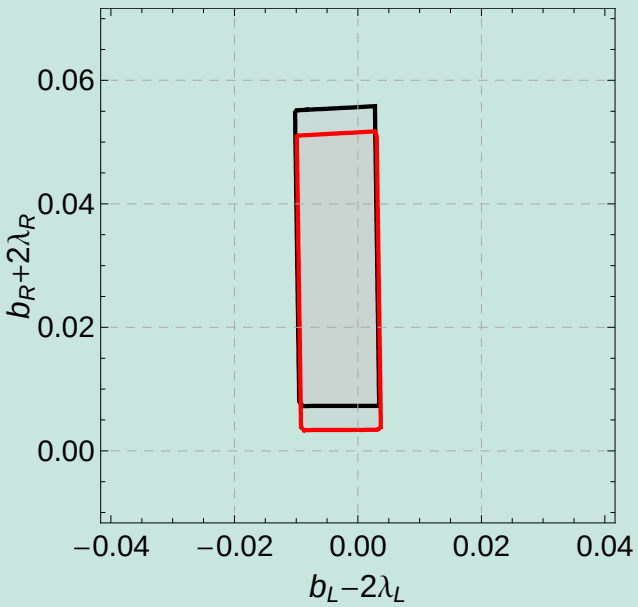
The intersections of the 90% C.L. allowed regions.

fine-tuning $< 10\%$ $\Rightarrow$ $|b_L| \leq 0.13$

Low-energy limits

on fermion parameters

ϵ_1, ϵ_b, $B \to X_s\gamma$

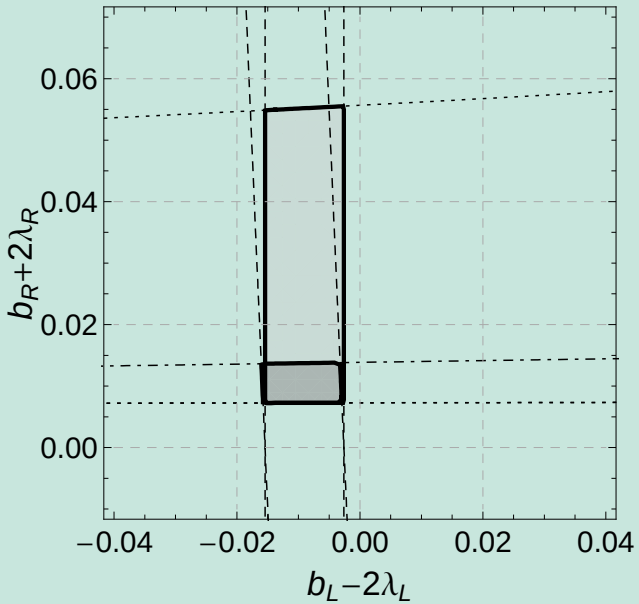


$g'' = 10$
$g'' = \infty$

$\Lambda = 2$ TeV

$p = 0, 0.5$

ϵ_1, $\Gamma(Z \to b\bar{b})$, $B \to X_s\gamma$



The intersections of the 90% C.L. allowed regions.

fine-tuning $< 10\%$ $\Rightarrow$ $|b_L| \leq 0.13$