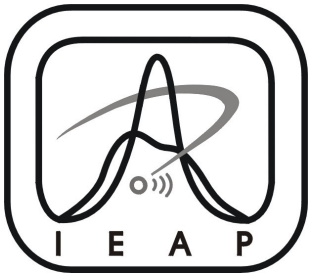
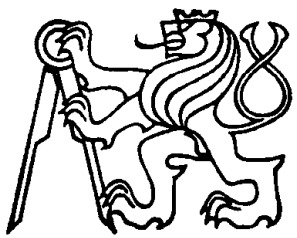
top-BESS model

and its phenomenology





Josef Juráň
Institute of Experimental and Applied Physics
Czech Technical University in Prague

Mikuláš Gintner, Ivan Melo
Physics Department
University of Žilina

Outline

- Introduction
- **top-BESS model**
- Parameter`s restriction

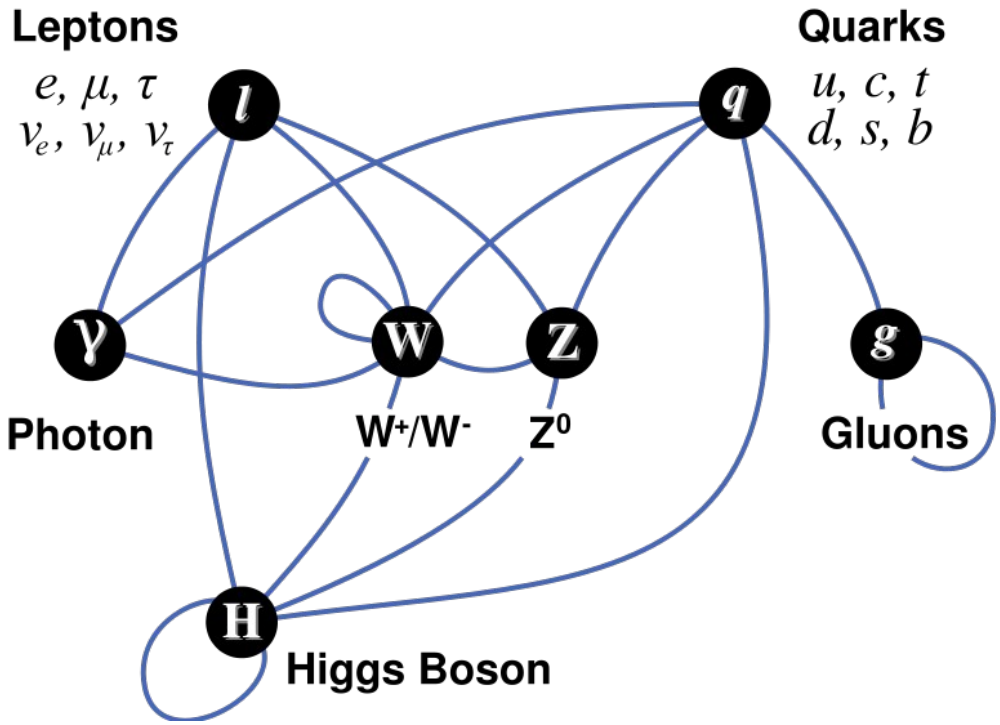
  (Unitarity and low-energy limits)
- Phenomenology of the model

  (Decay width, death Valley)
- Experimental devices
- Conclusion

Introduction

Standard Model (SM)

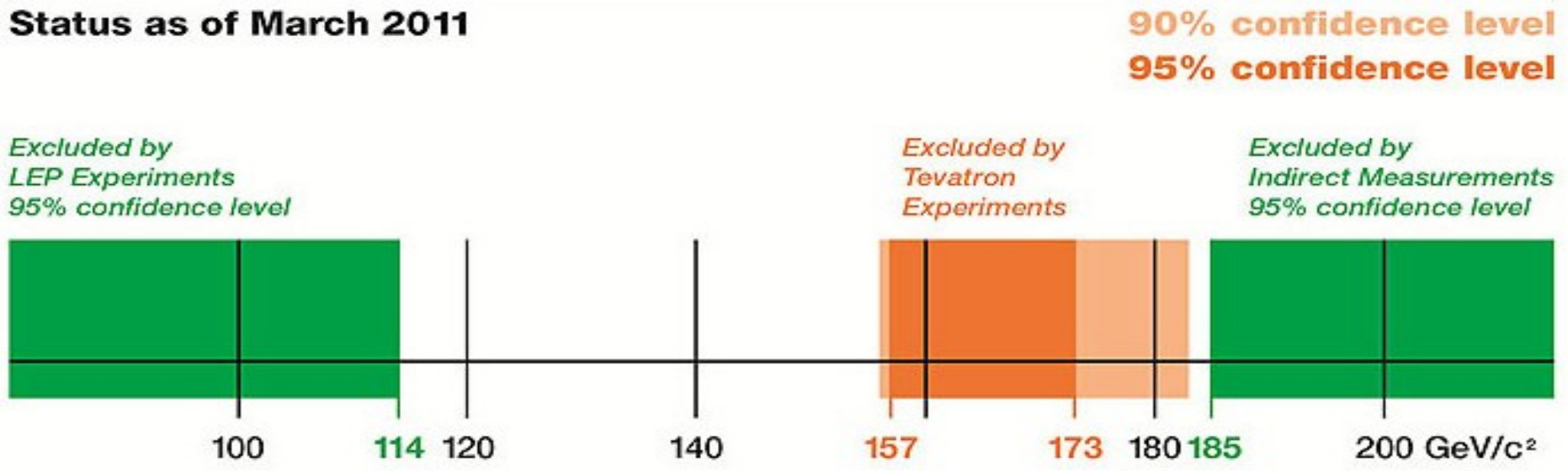
- the theory of microworld
- elementary particles + their interactions



- successful theory, many predictions, exp. verified (E ~ 200 GeV)
- not final theory (gravity, many free params., ESB? - no Higgs)

Introduction

- **E**lectroweak **S**ymmetry **B**reaking (ESB)
- massless Z and W, mass generation, Higgs searches



Beyond the SM

- SUSY, Technicolor, extradimensions, ...
- fundamental theory ---> effective theory
- SM as a (low-energy) part of a new theory

top-BESS model

- effective description of ESB
- **B**reaking **E**lectroweak **S**ymmetry **S**trongly
- Particles: SM particles, no Higgs, + new resonance
  (bounded state of new Sin)

Model = Lagrangian

- modification: in the **fermion** sector
- motivation: m_t (too big and close to the scale of ESB)

top-BESS vs BESS

- direct coupling of new resonance to 3rd generation of quarks only
- new terms in the Lagrangian
- model parameters: v, g, g', g'', alpha, b_L, b_R, p, Λ_L, Λ_R

Parameter`s restriction

Restriction of the parameters:

- unitarity limits
- low-energy limits

Unitarity limits

- conservation of probability
- $P \sim |\ \langle \text{final state} |\ S\ | \text{initial state} \rangle\ |^2$
- $SS^\dagger = 1$

Low-energy limits

- tBESS – eff.description of a HE extension of the Higgsless SM
- **E**lectro**W**eak **P**recision **D**ata (low-energy measurement)
- EWPD restrict tBESS deviations from the SM

Unitarity limits

to all processes ---> 1 process, a group of processes
(approximation: tree level, equivalence theorem)

Higgsless SM

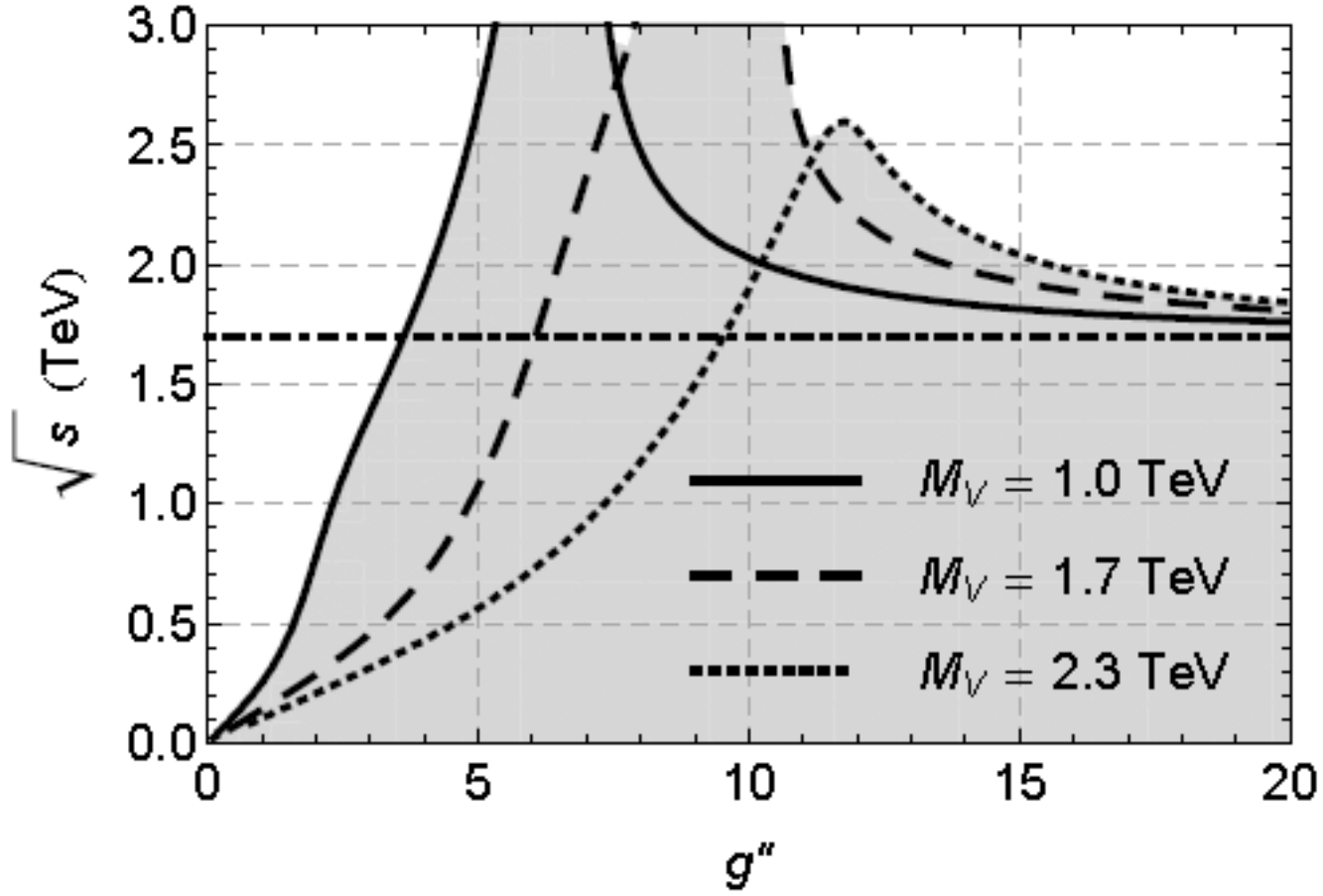
- scattering of longitudinal W and Z bosons
- U-limit: E = 1700 GeV
- Higgs (m_H < 1TeV) shifts this U-limit (up to 10^{19} GeV)

$$M(W_L^+W_L^- \to Z_LZ_L)$$
$$M(W_L^+W_L^- \to W_L^+W_L^-)$$
$$M(Z_LZ_L \to Z_LZ_L)$$
$$M(W_L^\pm Z_L \to W_L^\pm Z_L)$$
$$M(W_L^\pm W_L^\pm \to W_L^\pm W_L^\pm)$$

top-BESS model

- new resonance shifts this U-limit too
- effective model ---> U-violation at some energy (3000 GeV)

Unitarity limits



Constraints on g'' (dot-dashed SM U-limit).

For $b_L = b_R = 0$ (p is eliminated), λ`s negligible.

Low-energy limits

- low-energy top-BESS Lagrangian
  (integrating out the ρ resonance, M_V --> ∞, g'' fixed, subst. EoM)
- **ε`s analysis**: ε_1 and ε_3 (A'_{FB} and $\Gamma_{Z\to ll}$), ε_2 (+ M_W/M_Z), ε_b (+ $\Gamma_{Z\to bb}$)

$$g'' \geq 9.5(10.9) \ @ \ 95(90)\% \text{ C.L.}$$

90% C.L.
$p = 0$
$\Lambda = 1$ TeV
$g'' = 10$

$$-0.010 \leq b_L - 2\lambda_L \leq 0.003$$
$$-0.031 \leq b_R + 2\lambda_R \leq 0.033$$

BESS limits: $0.006 \leq b \leq 0.011$ $\quad b' = 0$

Our modifications relax the low-energy limits (thanks to λ`s and p).

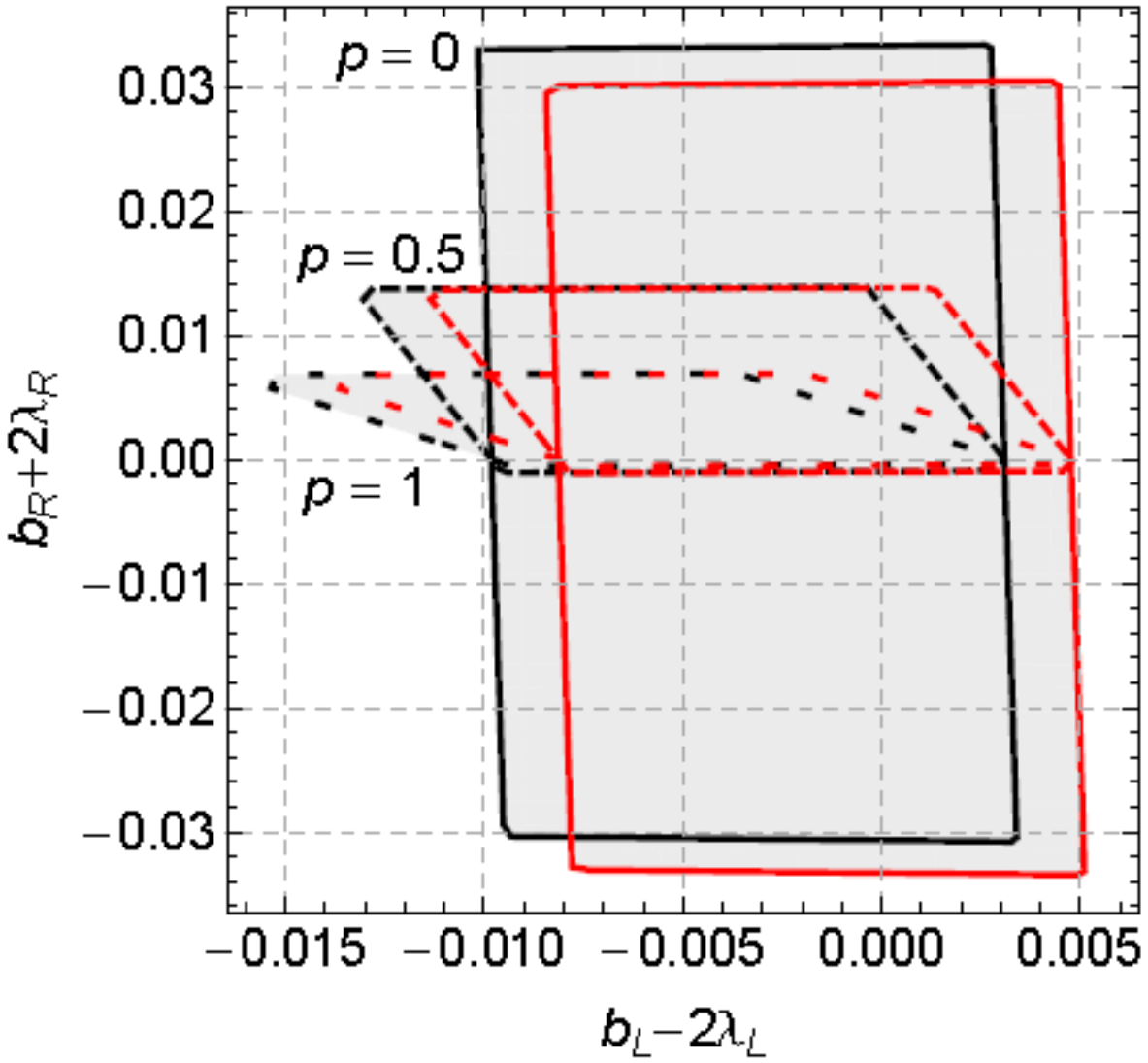
Low-energy limits

A few measurements

- ε`s analysis
- measurement

$$B \to X_s \gamma$$

- GB`s self-interaction anomalous WWZ



An **intersection**

of the allowed 90% C.L. regions

of ε_1, ε_b, and b --> sγ for Λ = 1 TeV and g'' = 10, g'' --> ∞

Phenomenology of the model

Particles: top-BESS = SM\{H} + new resonance

Properties of the new resonance:

- **Isospin** 1 – triplet: V^+ V^- V^0 [rho]
- **Spin** 1 – vector (like W, Z bosons)
- **Mass** = M(alpha, v, g, g', g'')
  alpha and g'' are free

mass degeneracy < 1 per mil if g''>8

$$M_{V^\pm} = \frac{\sqrt{\alpha} v g''}{2}\left(1+\frac{g^2}{2g''^2}\right)$$

$$M_{V^0} = \frac{\sqrt{\alpha} v g''}{2}\left(1+\frac{G^2}{2g''^2}\right)$$

$G^2 = g^2 + g'^2$

M_{V0} = 1000 GeV

M_p = 1 GeV

$M_{W(Z)}$ ~ 80 (91) GeV

- **Decay width** Γ (GeV)

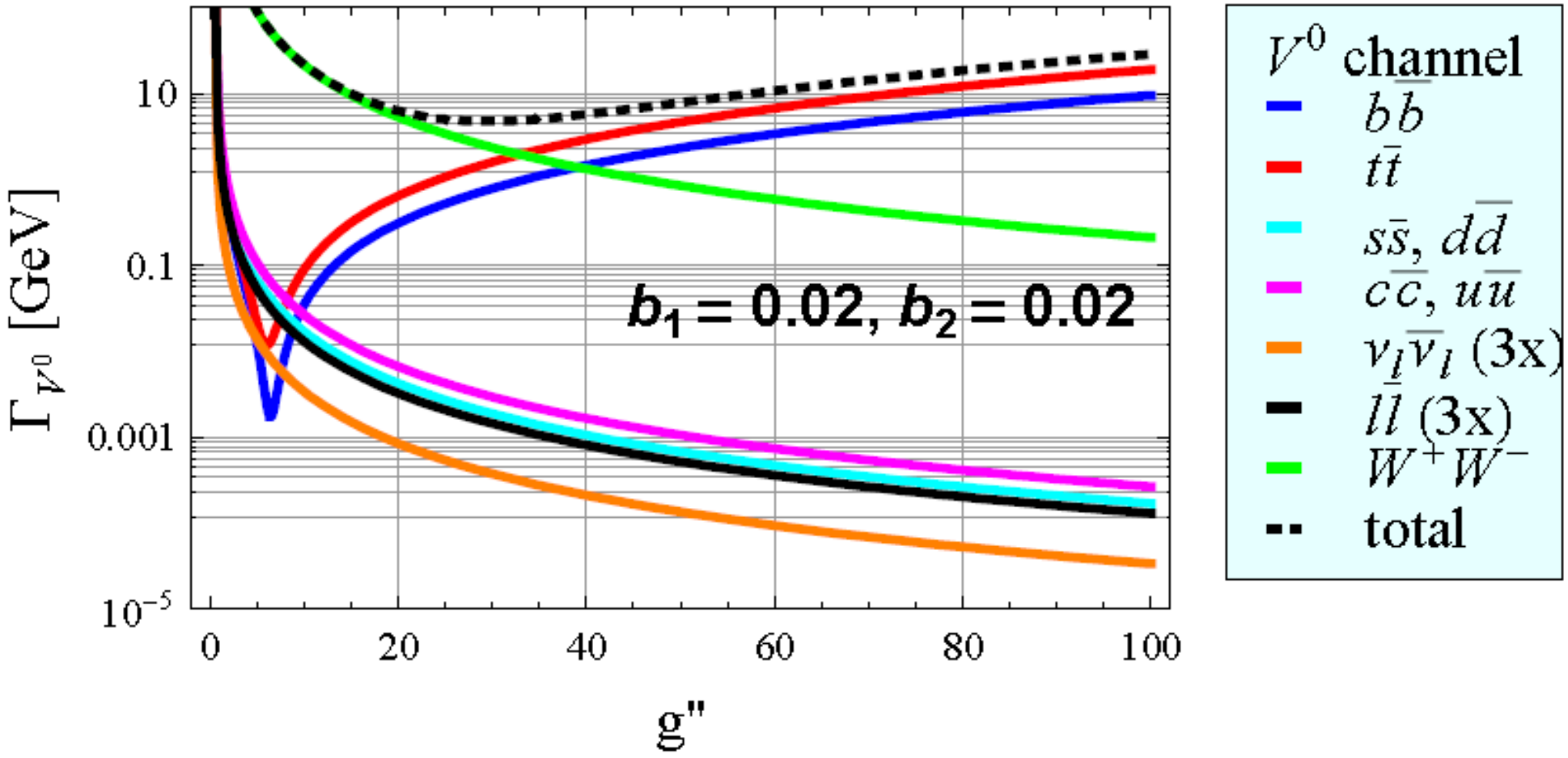
Γ ~ 1 / lifetime

mion: τ ~ 10^{-6} s --> Γ ~ 10^{-19} GeV

particle – versus – resonance (Γ > MeV)

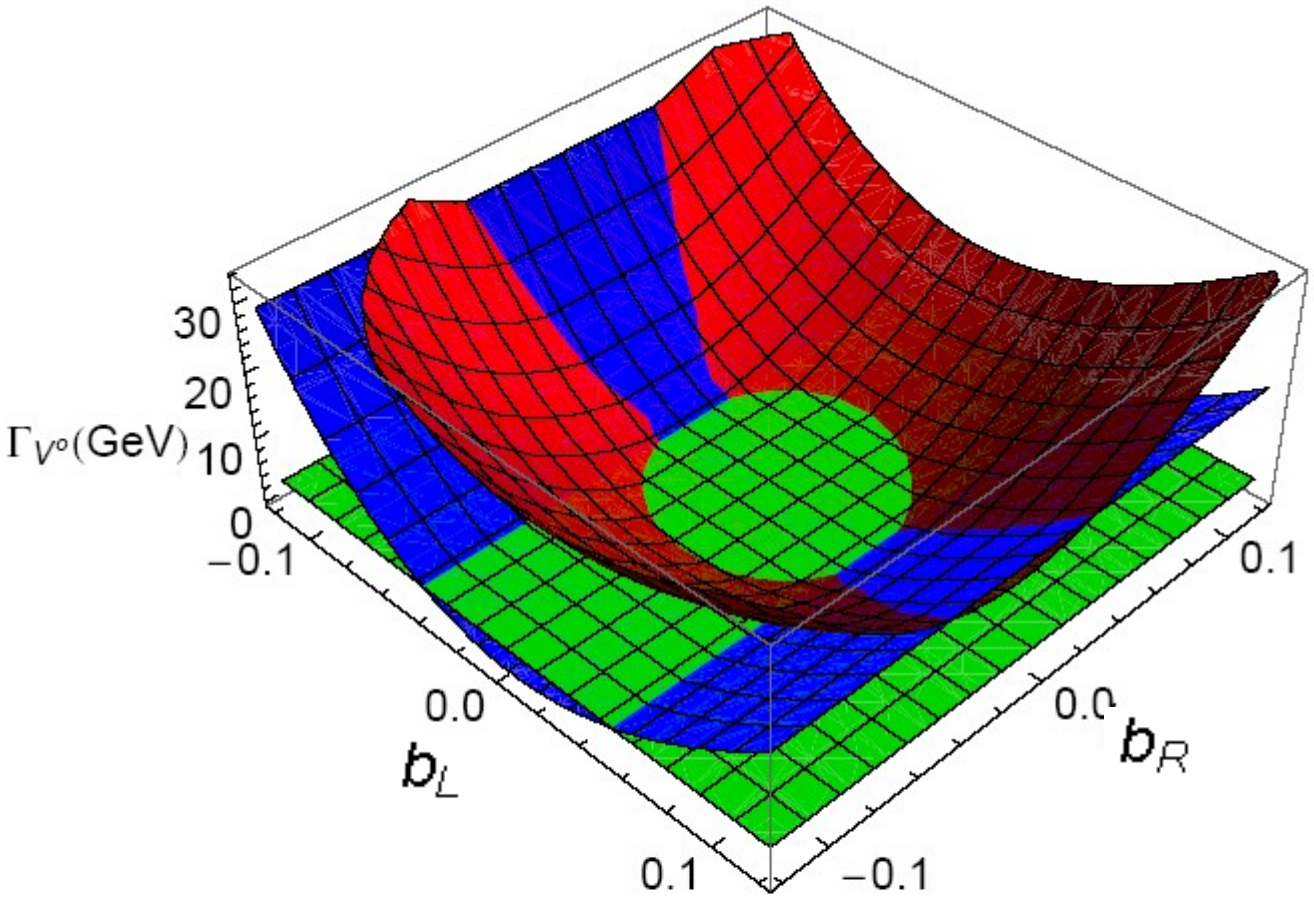
7 (charged) and 13 (neutral) decay channels (param. dependence)

Partial decay widths



Neutral resonance with M_{v0} = 1000 GeV (p = 0, λ`s = 0).

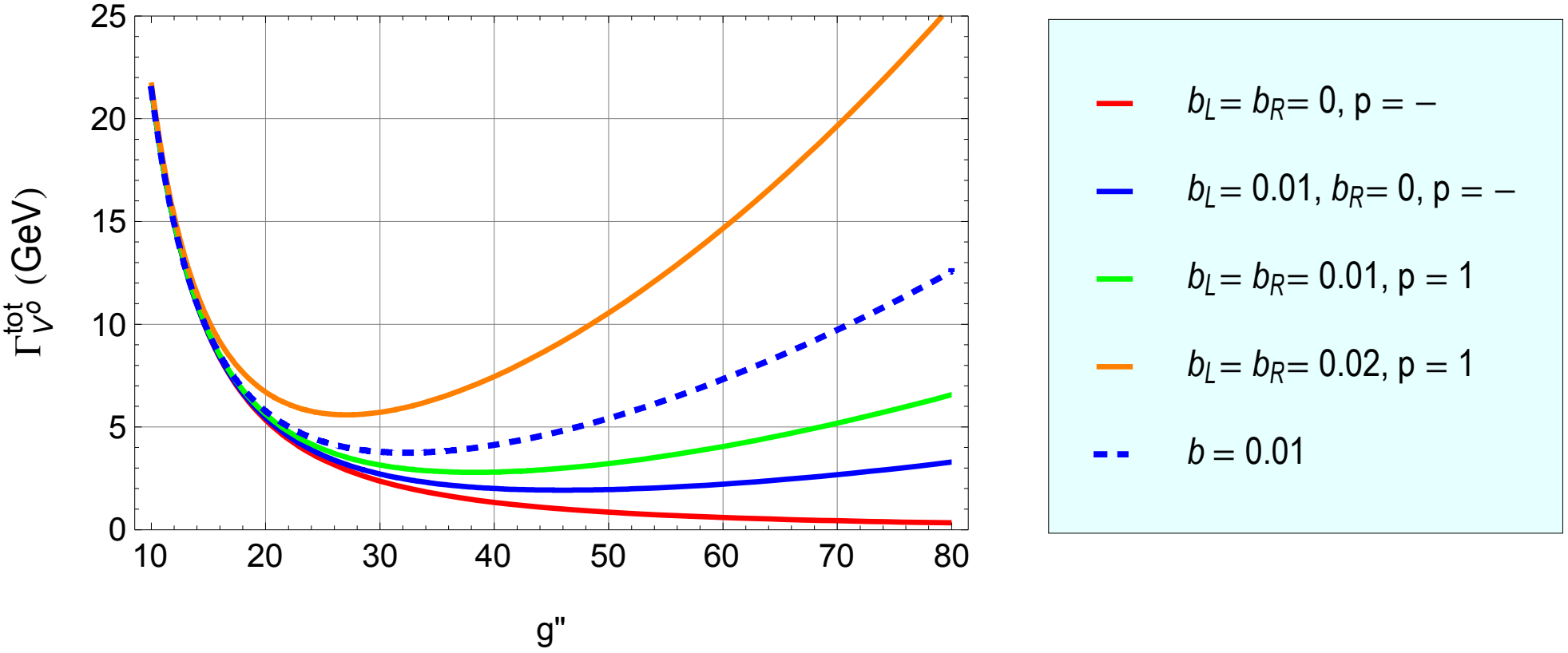
Dominant partial decay widths



Neutral resonance with M_{v0} = 1000 GeV (g''=25, p=0, λ`s = 0).

W^+W^-, $b\bar{b}$, $t\bar{t}$ channels

Total decay width



Neutral resonance with M_{v0} = 1000 GeV (λ`s = 0).

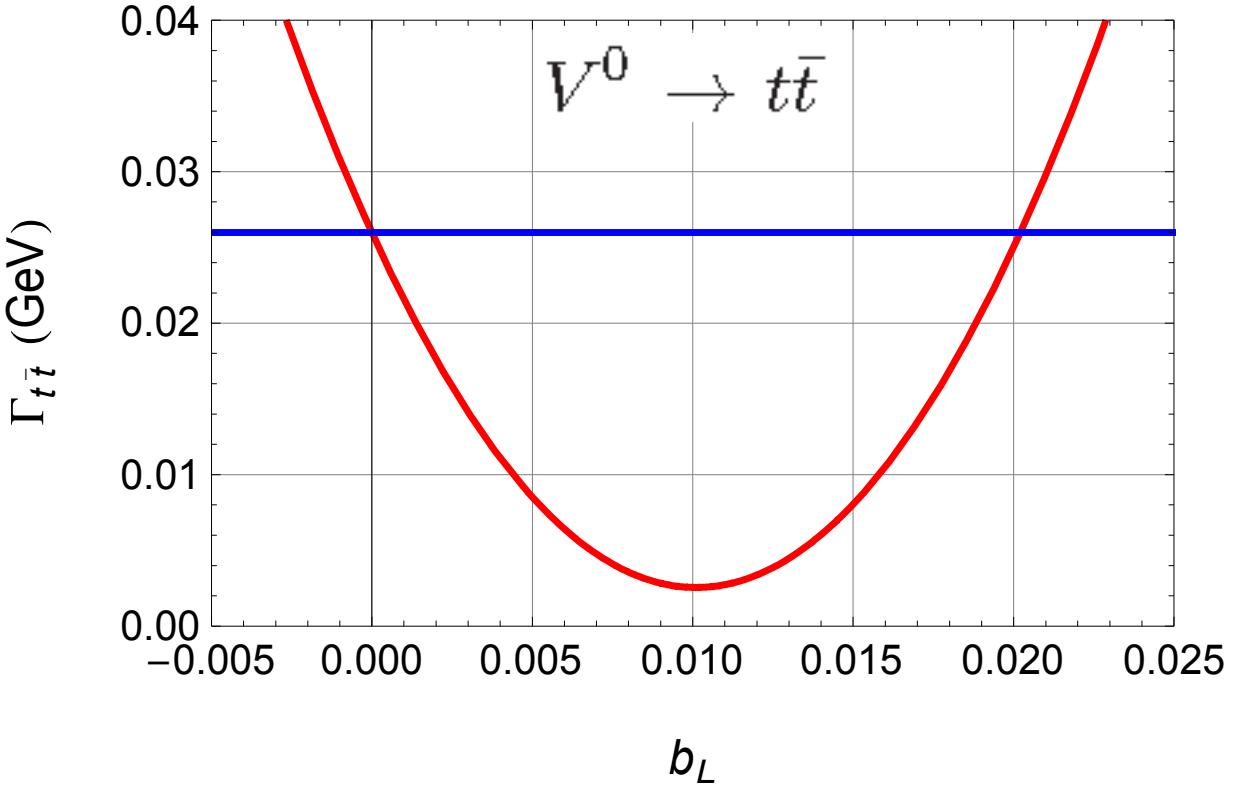
Dashed line is BESS model.

Gauge Boson mixing

Decay width, Cross section ~ coupling^2

direct coupling of V to t and b ~ b_L and b_R (.p)

for b = 0 also V --> t, b (why V --> e^+ e^- if direct interaction is off)



M_{V0} = 1000 GeV

g'' = 10

b_R = 0

λ`s = 0

Gauge Boson mixing ---> interplay of direct and indirect couplings

The Death Valley

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

Γ_{tt} (b`s=0) = 0.026 GeV

increasing

the direct interaction,

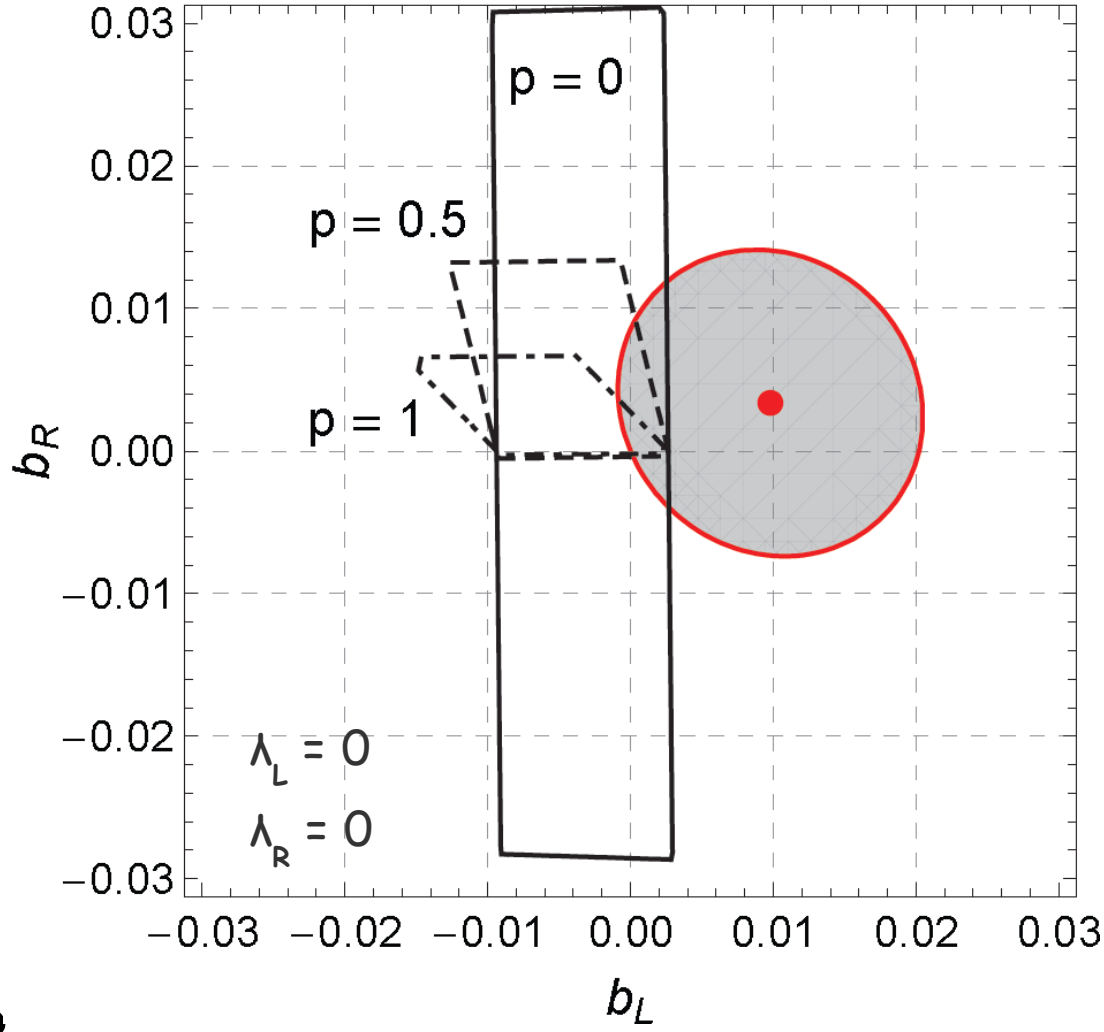
i.e. increasing |b`s|

→

but decay can diminish

Q1: Are there such b`s that the decay is forbidden ?

Q2: If yes, are they allowed by Unitarity and LE limits ?



M_{V0} = 1000 GeV, g`` = 10

λ`s-shift of the LE region

The Death Valley

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

Γ_{tt} (b`s=0) = 0.026 GeV

increasing

the direct interaction,

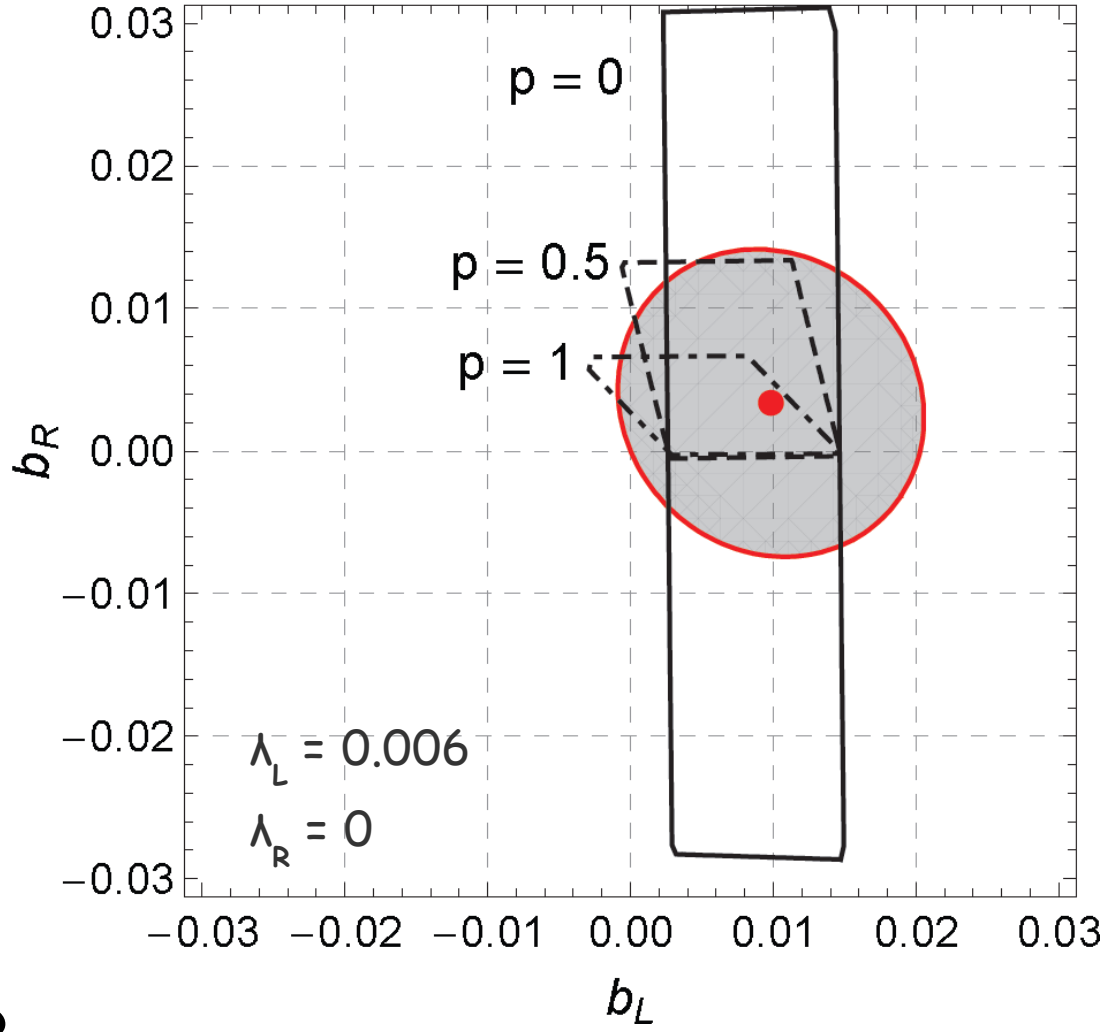
i.e. increasing |b`s|

→

but decay can diminish

Q1: Are there such b`s that the decay is forbidden ?

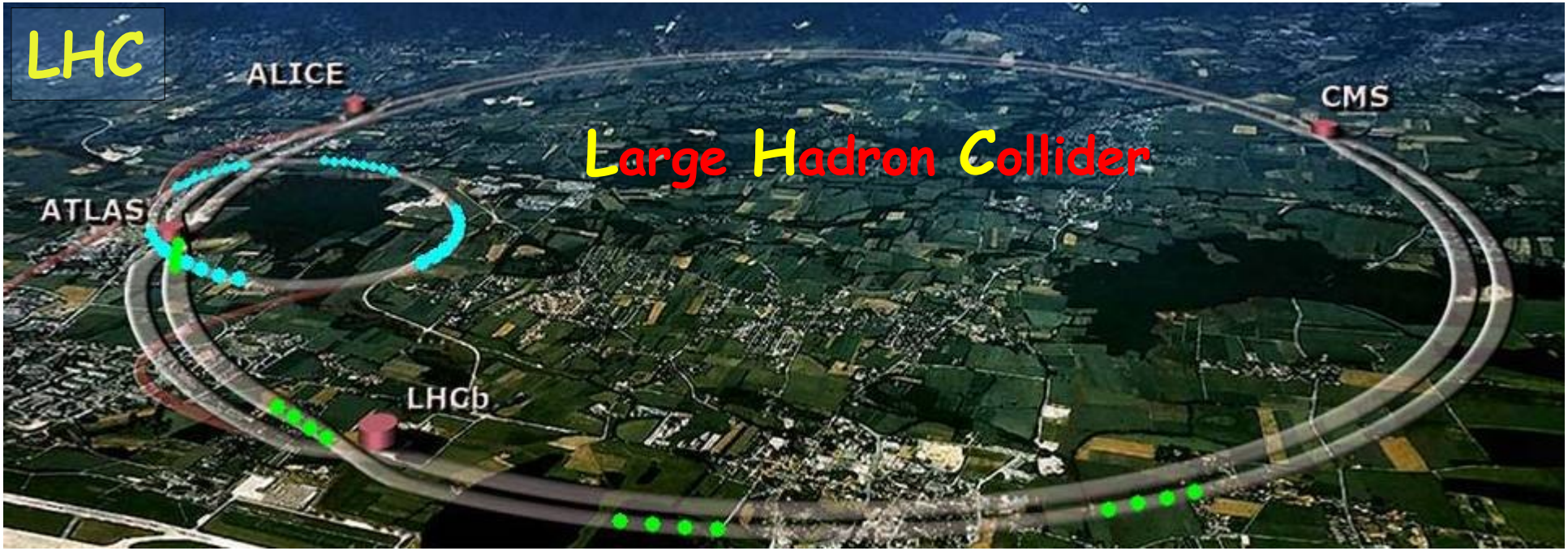
Q2: If yes, are they allowed by Unitarity and LE limits ?

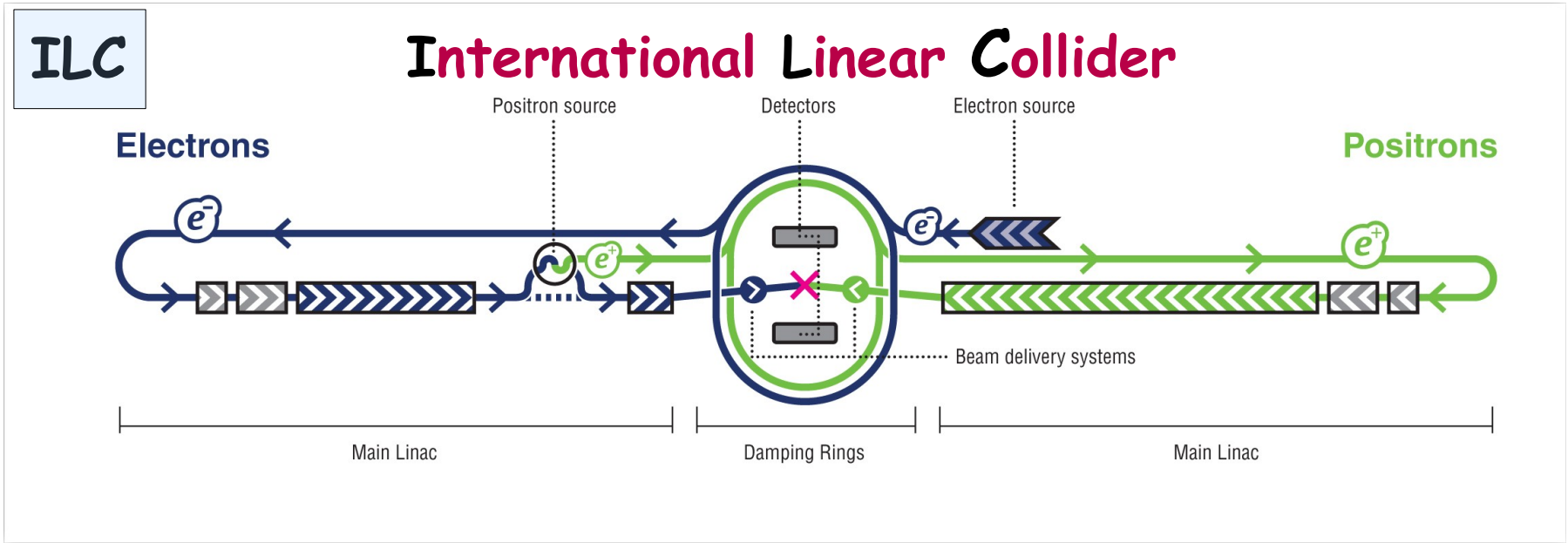


M_{V0} = 1000 GeV, g'' = 10

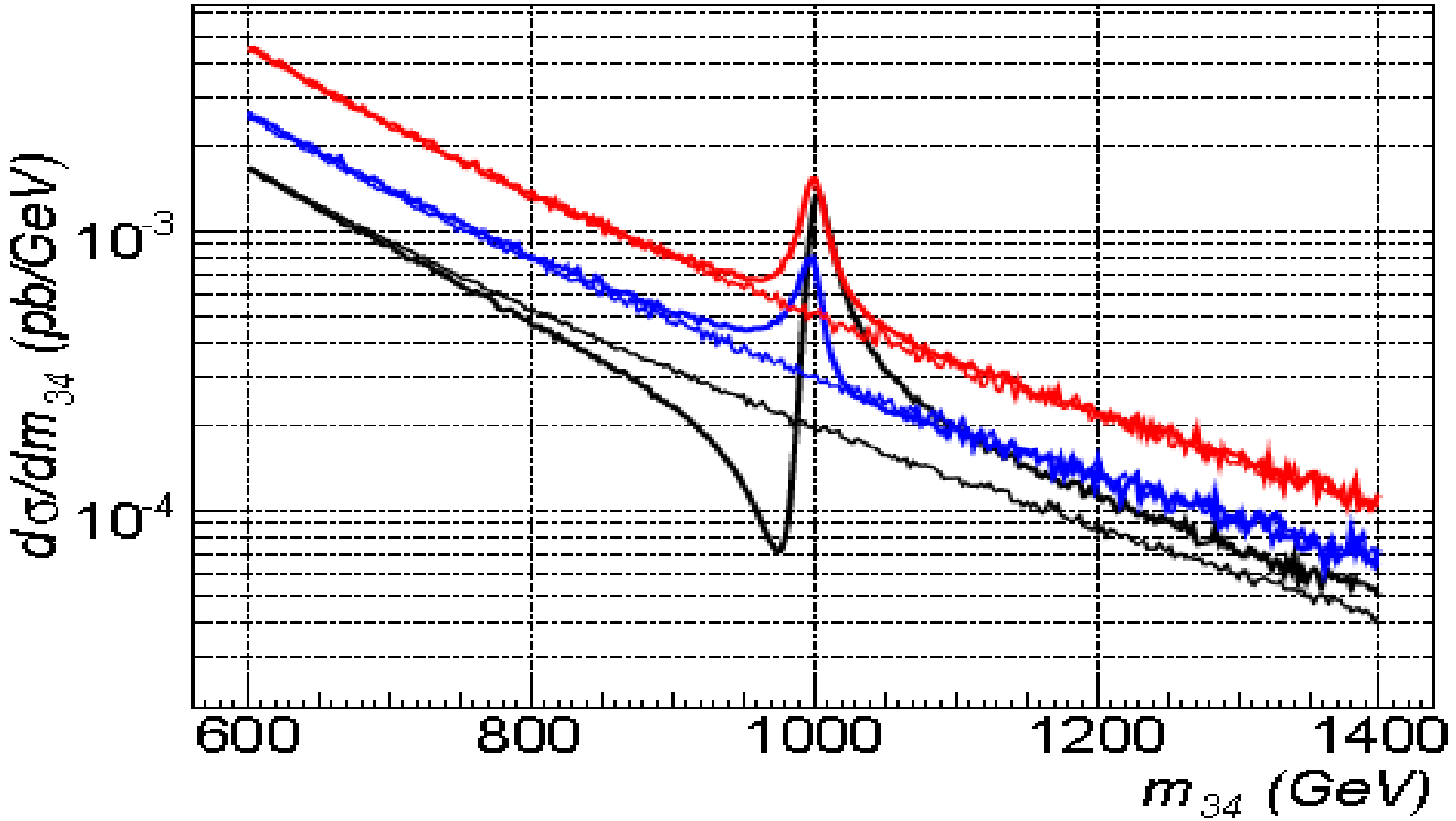
λ`s-shift of the LE region

Experimental devices





top-BESS model @ LHC

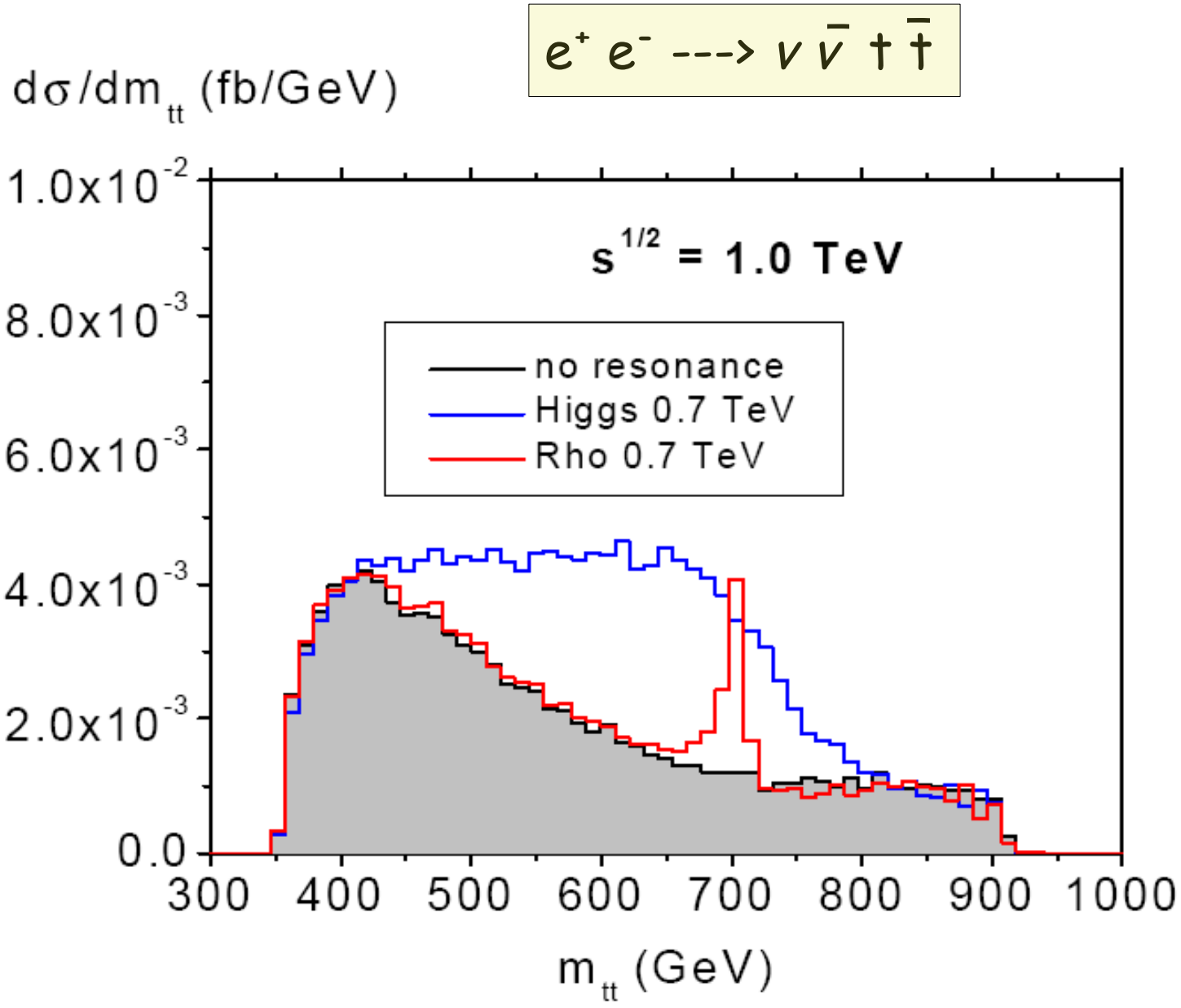


The invariant mass distributions for the final state particle of the p p ---> W⁺ W⁻ X, p p ---> W Z X, p p ---> t b X processes

for sqrt(s) = 14TeV, M_{V0} = 1 TeV, g'' = 20, p = 0.5, b_L = -0.072, b_R = 0.074, λ`s = -0.03.

The thinner lines depict the SM predictions assuming M_{Higgs} = 115 GeV.

top-BESS model @ ILC



The effect of the Death Valley

The cross section

$e^+ e^- \dashrightarrow W^+ W^-$

$u \bar{d} \dashrightarrow W^+ Z$

$e^+ e^- \dashrightarrow t \bar{t}$

$u \bar{d} \dashrightarrow t \bar{b}$

$e^+ e^- \dashrightarrow b \bar{b}$

$M_{V0} = 1000$ GeV

$g'' = 20$

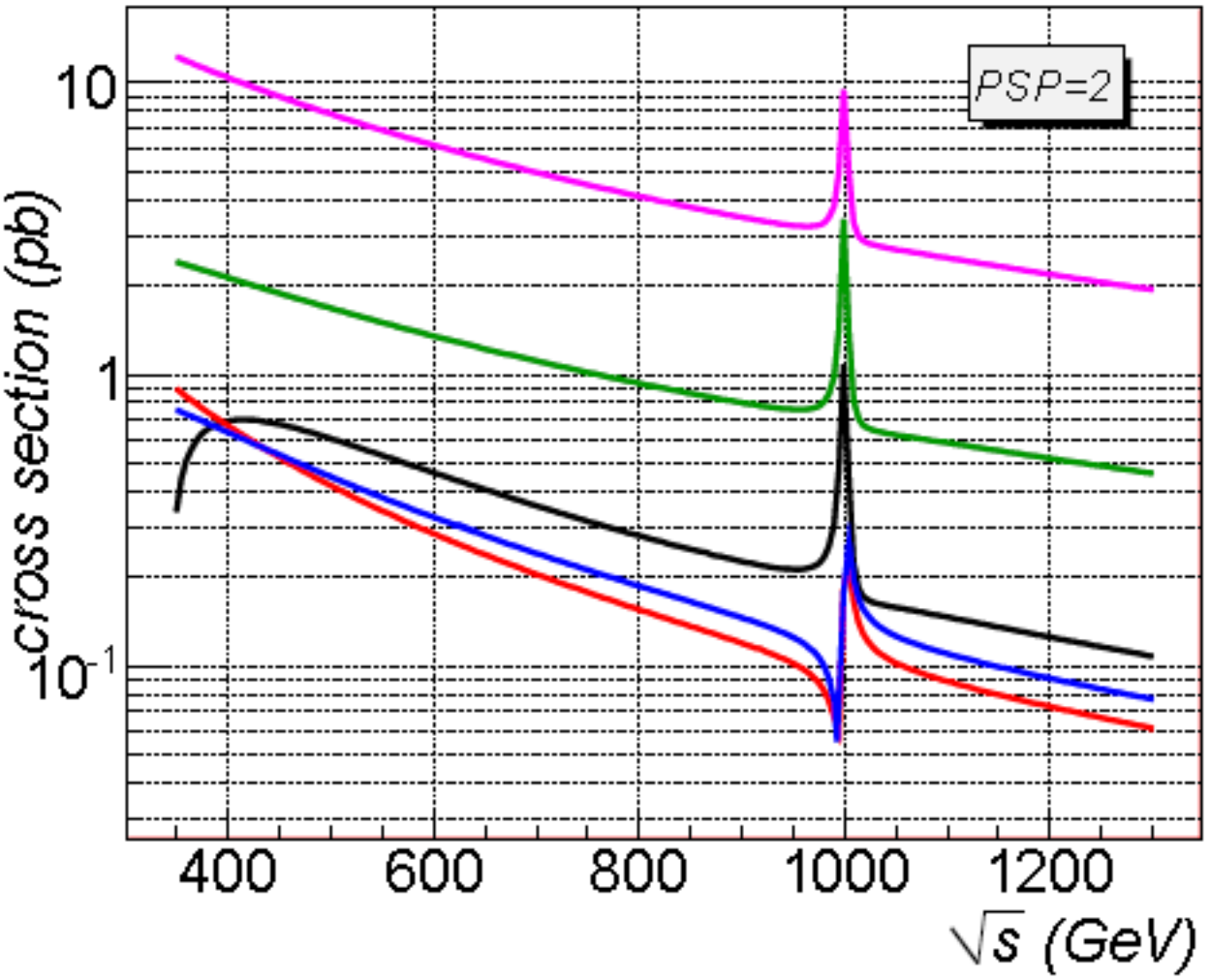
$p = 0$

$b_L = -0.01$

$b_R = 0.03$

$\Lambda_L = 0$

$\Lambda_R = 0$



The effect of the Death Valley

The cross section

$e^+ e^- \rightarrow W^+ W^-$

$u \bar{d} \rightarrow W^+ Z$

$e^+ e^- \rightarrow t \bar{t}$

$u \bar{d} \rightarrow t \bar{b}$

$e^+ e^- \rightarrow b \bar{b}$

M_{V0} = 1000 GeV

$g'' = 20$

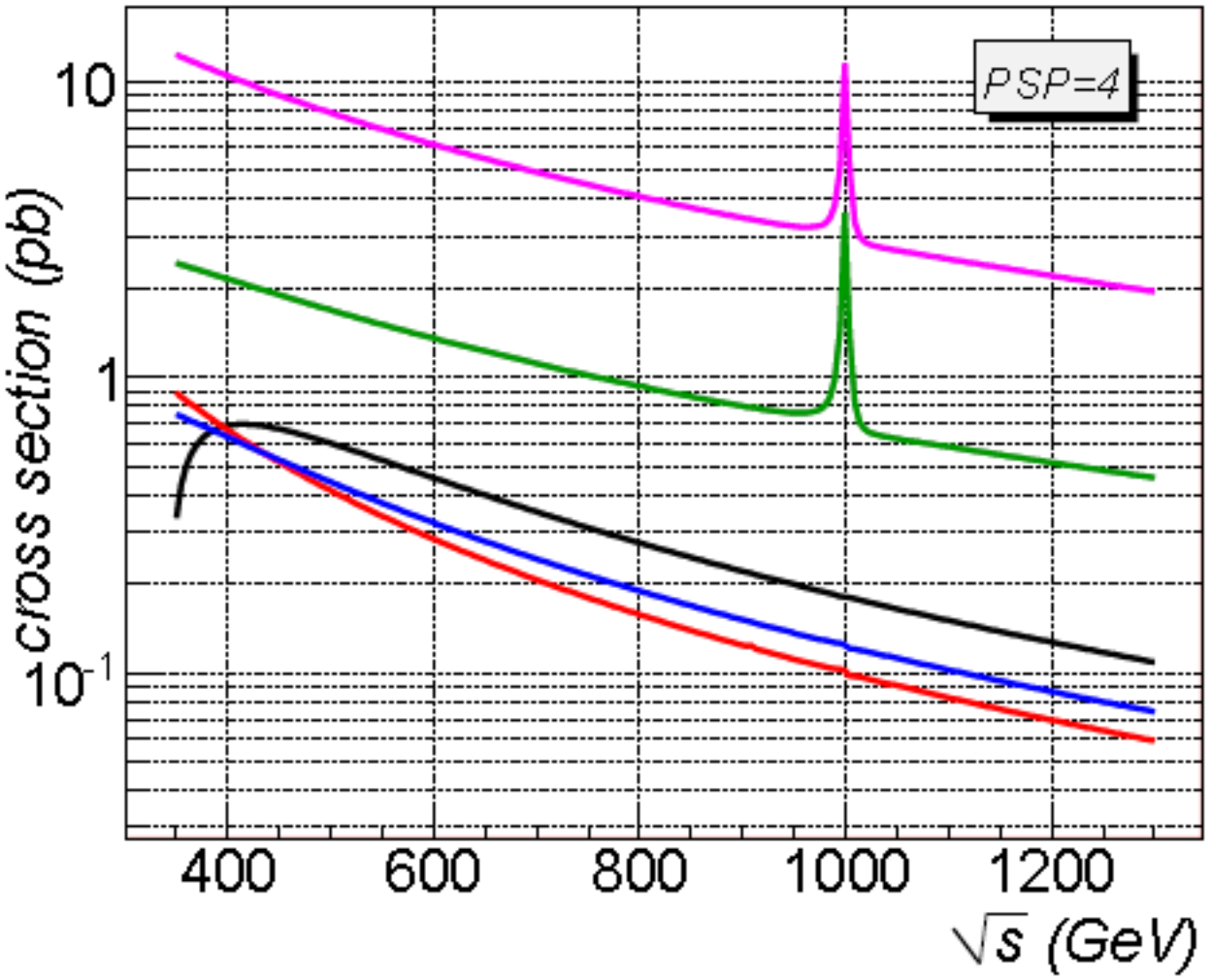
$p = 0$

$b_L = 0.0098$

$b_R = 0.0034$

$\Lambda_L = 0.006$

$\Lambda_R = 0$



Conclusion

- top-BESS model as eff. description of a subgroup of fund. models
- **BESS** ⟶ **top-BESS** (m_t motivation, fermion sector modification)

- direct coupling of new triplet to the 3rd generation of quarks only
- new **p** parameter
- new **λ**-terms

- relaxing the L-E limits on the original BESS model`s parameters
- sizeable signal of top-BESS model at the LHC and ILC
- the Death valley effect (hiding the peak)

- paper submitted to **Physical Review D**
- the first referee response is back

Thank you for your attention.