The Higgs and Leptophobic Force at the LHC

arXiv: 2003.09426

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Phenomenology 2020 Symposium

May 5, 2020

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CERCA

References

- This talk is based on
  - P. Fileviez Perez, EG, C. Murgui, and A. D. Plascencia, *The Higgs and Leptophobic Force at the LHC*, arXiv: 2003.09426

Main Goals

- Investigate novel decays of the Standard Model Higgs boson into leptophobic gauge bosons in a simple gauge theory at the low scale.
- Study the associated production of the SM Higgs and leptophobic gauge boson.
- We focus on $U(1)_B$ theory because it is the simplest gauge theory that can live at the low scale without assuming a very small gauge coupling.

Theory for Local Baryon Number: $U(1)_B$

- Gauge Group:

$$SU(3)_C \otimes SU(2)_L \otimes U(1)_Y \otimes U(1)_B$$
$$\downarrow \langle S_B \rangle \longleftarrow \text{New Higgs}$$
$$SU(3)_C \otimes SU(2)_L \otimes U(1)_Y + \mathbb{Z}_2$$
$$\downarrow \langle H \rangle \longleftarrow \text{SM Higgs}$$
$$SU(3)_C \otimes U(1)_{EM} + \mathbb{Z}_2$$

- Anomaly free theory which predict proton stability.
- Cold dark matter candidate with mass defined by the symmetry breaking scale
- SSB at the low scale compatible with experimental bounds

P. Fileviez Perez and M. B. Wise, *Baryon and lepton number as local gauge symmetries*, Phys. Rev. D82 (2010) 011901
P. Fileviez Perez and M. B. Wise, *Breaking Local Baryon and Lepton Number at the TeV Scale*, JHEP 08 (2011) 068
M. Duerr, P. Fileviez Perez and M. B. Wise, *Gauge Theory for Baryon and Lepton Numbers with Leptoquarks*, Phys. Rev. Lett. 110, (2013) 231801

Leptophobic Gauge Boson at the LHC

- Simple extensions of the SM with Baryon number as a local symmetry predict the existence of a leptophobic gauge boson:

$$Z_B$$

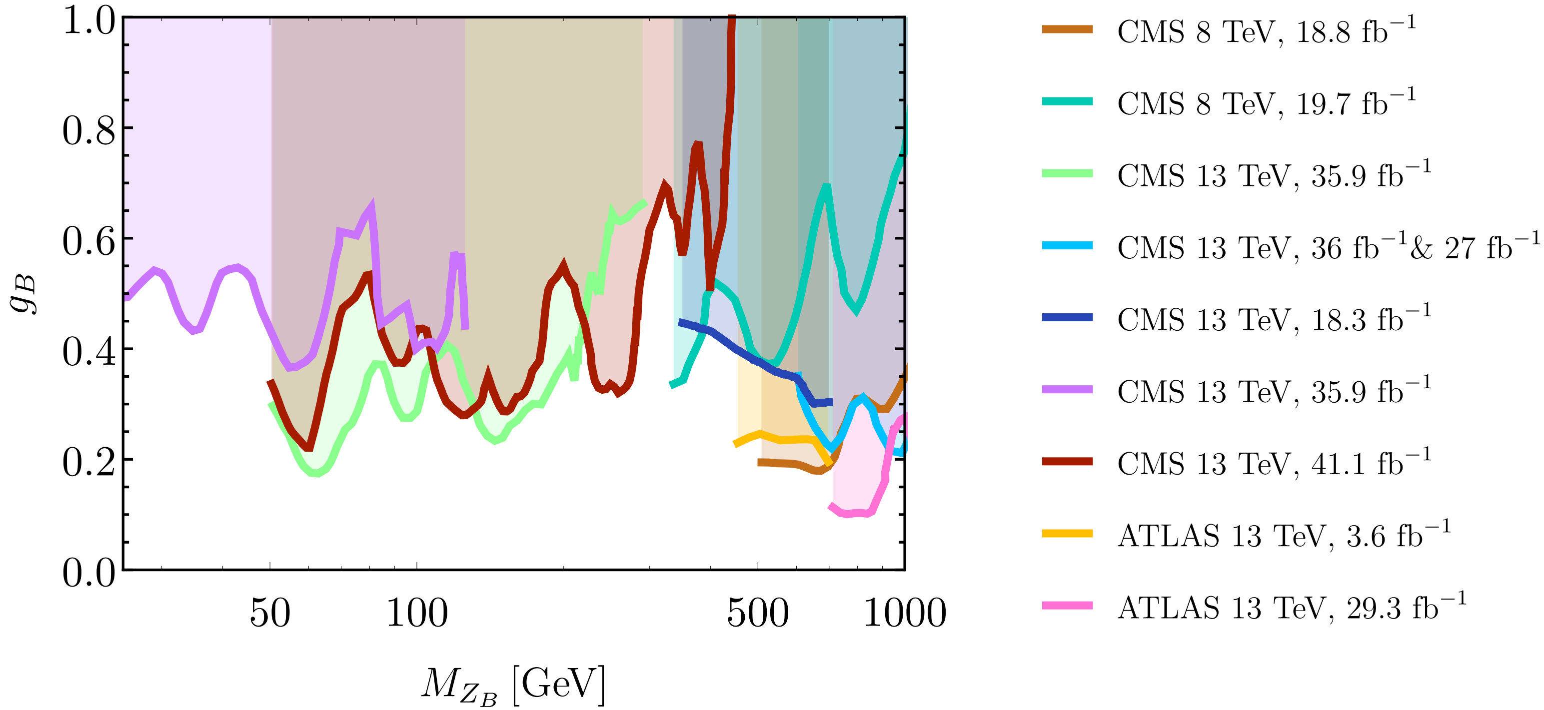
- Coupling between SM quarks and leptophobic gauge boson:

$$Z_B^\mu \bar{q} q : -i \frac{g_B}{3} \gamma^\mu$$

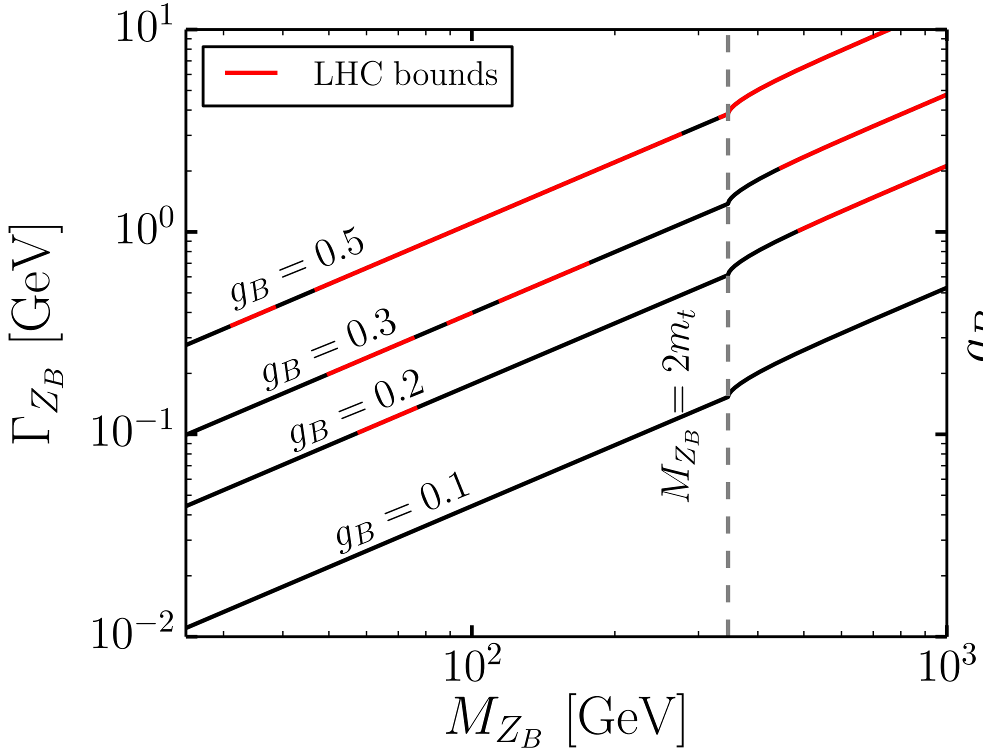
- Z_B-Higgs Couplings:

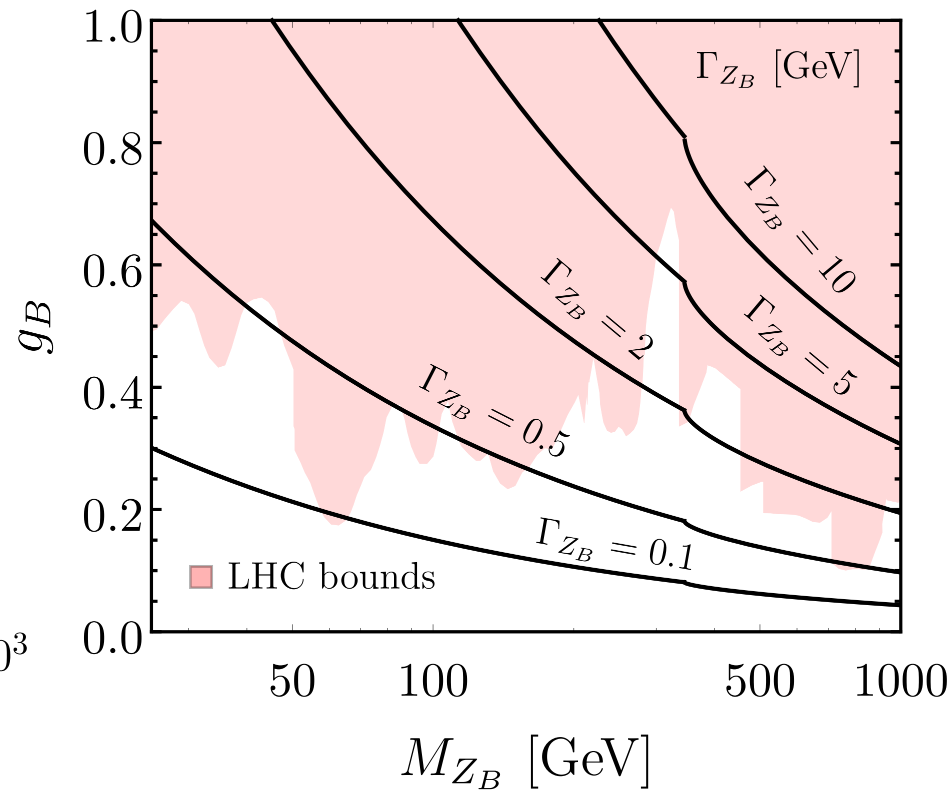
$$h Z_B^\mu Z_B^\nu : \; 2i \frac{M_{Z_B}^2}{v_B} g^{\mu\nu} \sin\theta_B$$

Leptophobic Gauge Boson at the LHC



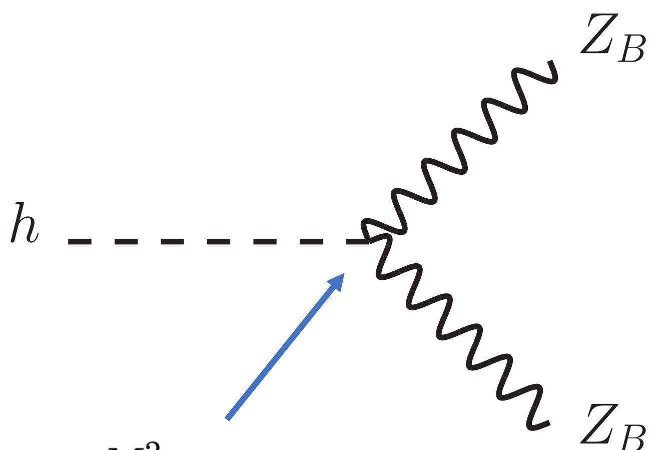
Leptophobic Gauge Boson at the LHC





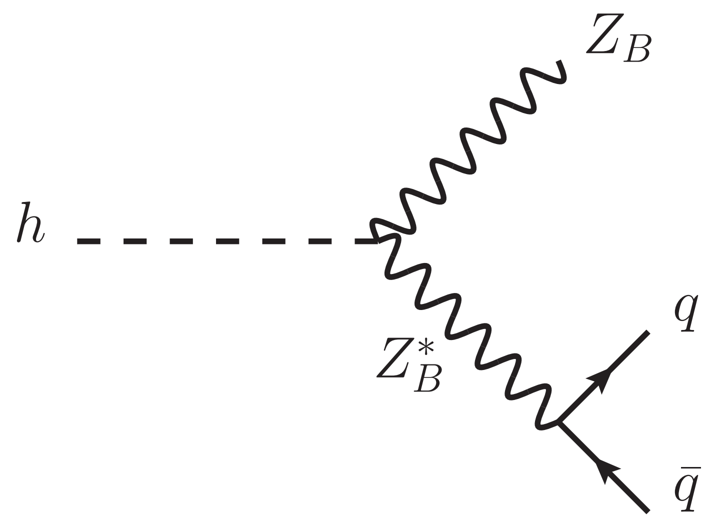
Exotic Decays of the SM-like Higgs

$h \to Z_B Z_B$



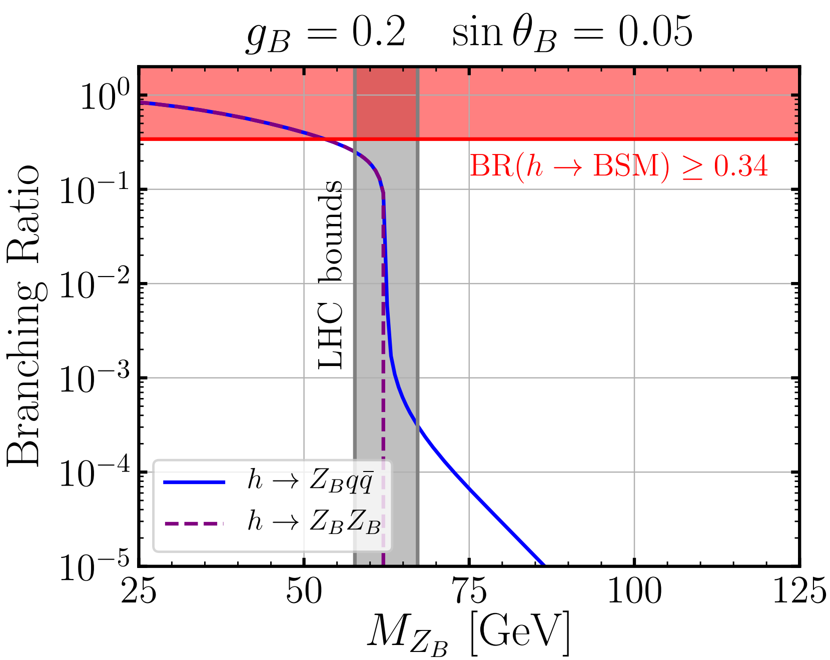
$$hZ_B^\mu Z_B^\nu : \; 2i\frac{M_{Z_B}^2}{v_B} g^{\mu\nu} \sin\theta_B$$

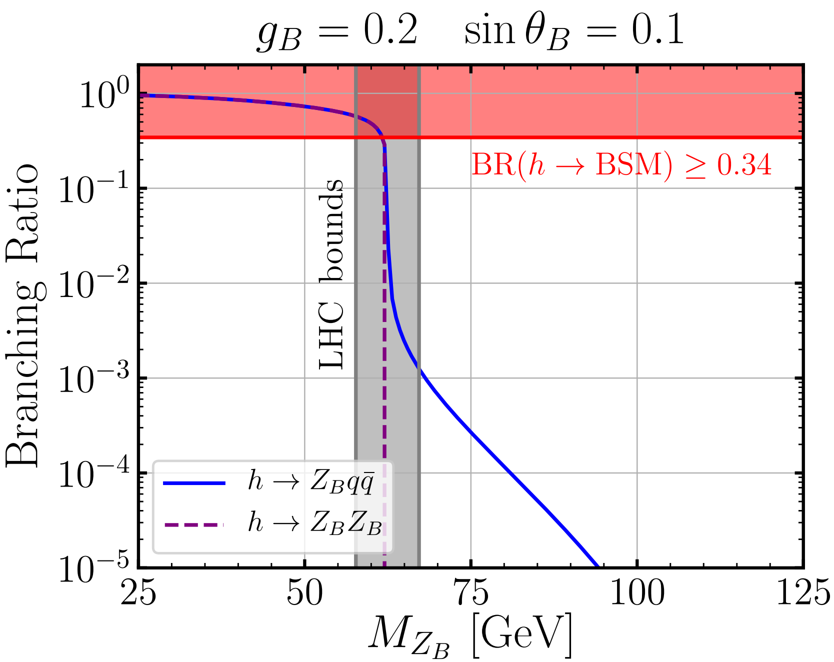
$h \to Z_B^* Z_B$



$$\Gamma_h = \cos^2\theta_B \Gamma_{\rm SM} + \Gamma_{\rm BSM}$$

Exotic Decays of the SM-like Higgs





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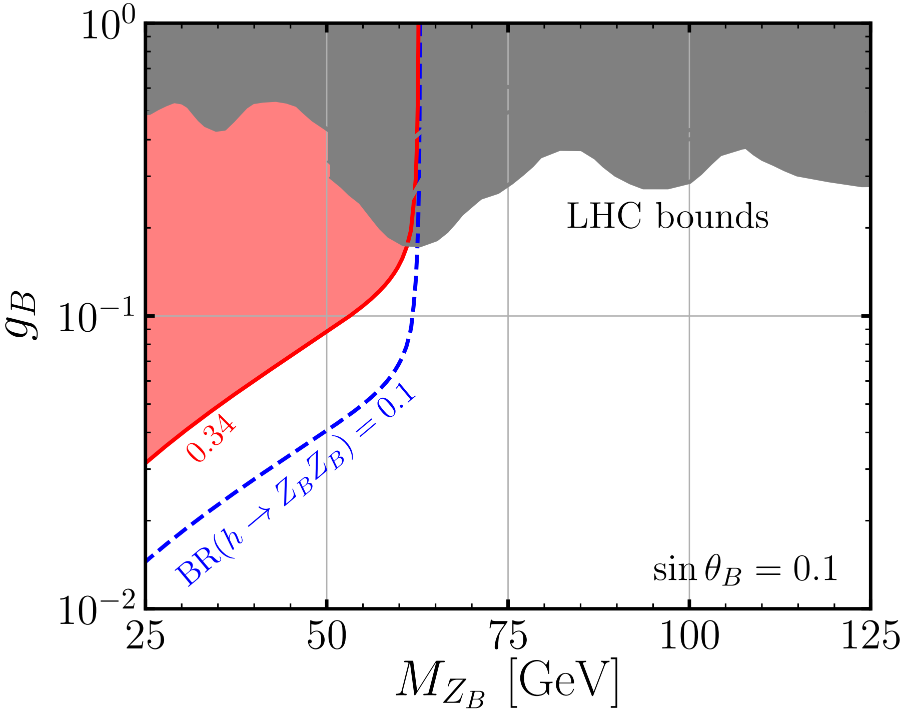
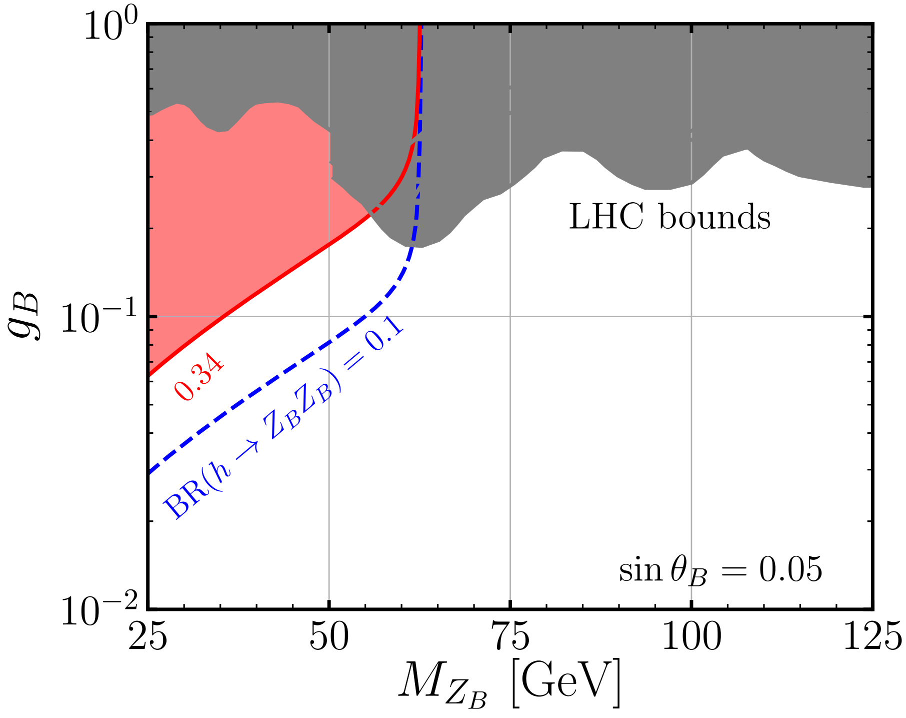
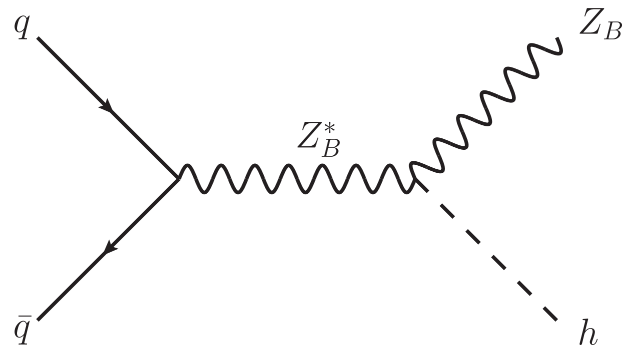
Exotic Decays of the SM-like Higgs

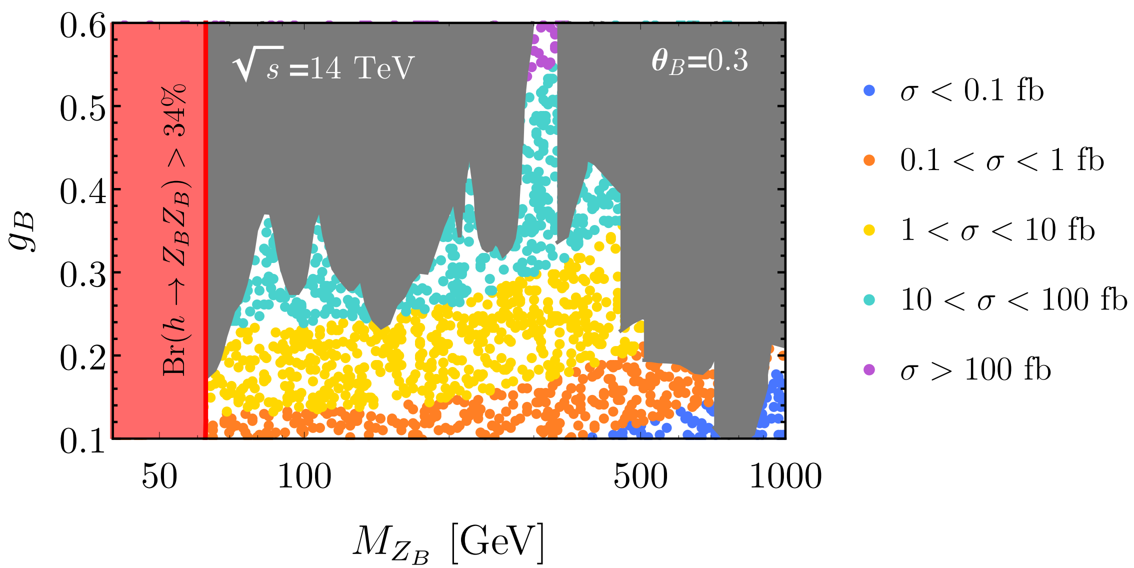




Higgs-Z_B Associated Production



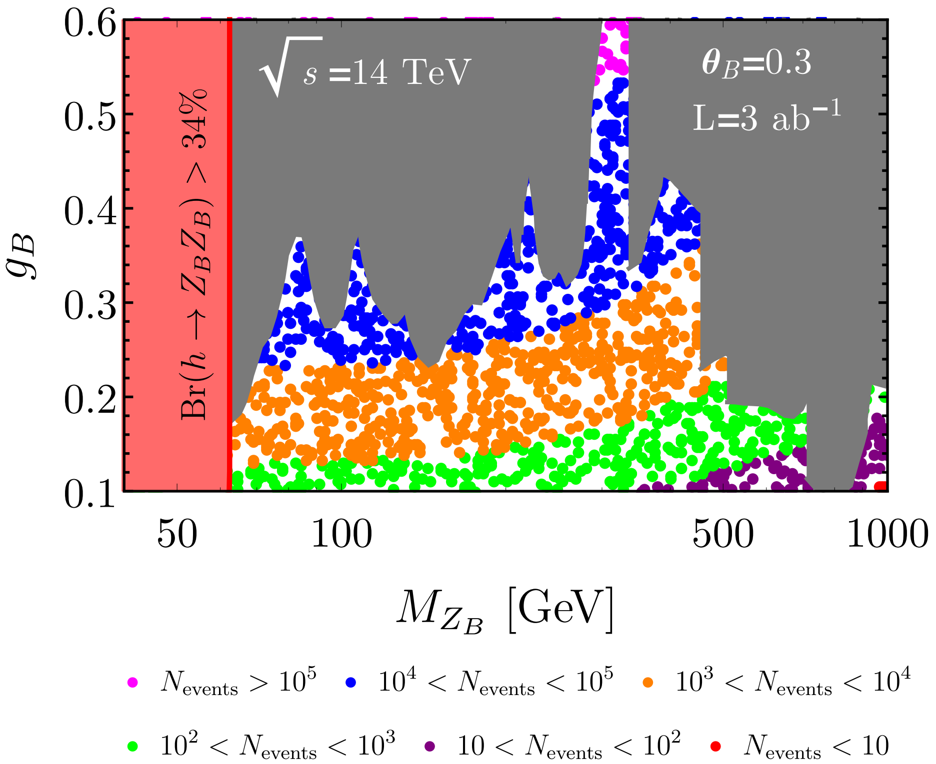
$\sigma(pp \to Z_B^* \to Z_B h)$



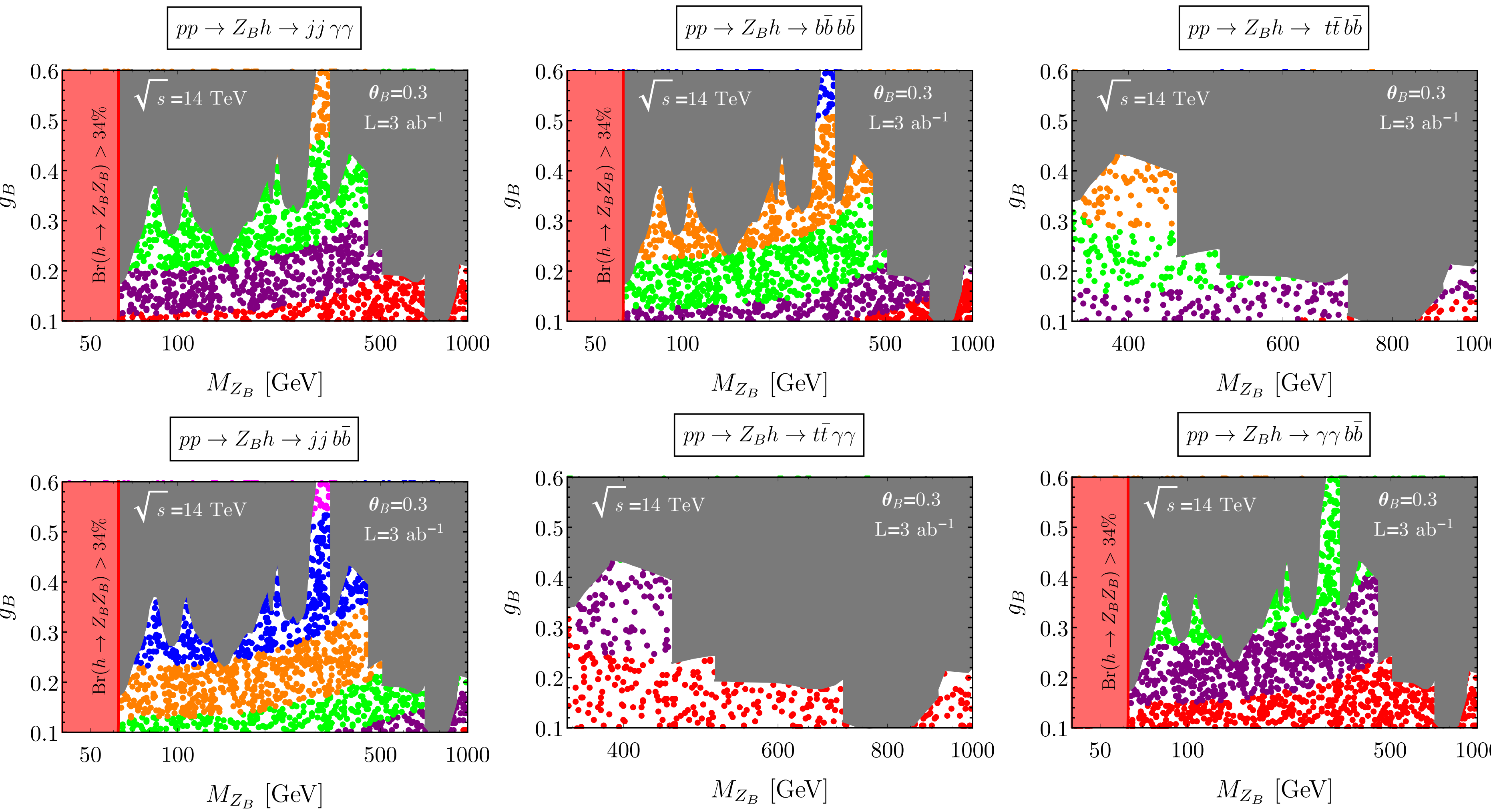
Higgs-Z_B Associated Production

$$N_{\rm events}(x\bar{x}y\bar{y}) = \mathcal{L} \times \sigma(p\,p \to Z_B^* \to Z_B\,h) \times {\rm Br}(h \to x\bar{x}) \times {\rm Br}(Z_B \to y\bar{y})$$

$$pp \to Z_B h \to jj\,b\bar{b}$$



Higgs-Z_B Associated Production



$N_{\text{events}} > 10^5$ $10^4 < N_{\text{events}} < 10^5$ $10^3 < N_{\text{events}} < 10^4$
$10^2 < N_{\text{events}} < 10^3$ $10 < N_{\text{events}} < 10^2$ $N_{\text{events}} < 10$

Summary

- The SM Higgs boson can open a doorway to new physics and the chance to discover a new sector through the existence of new interactions.

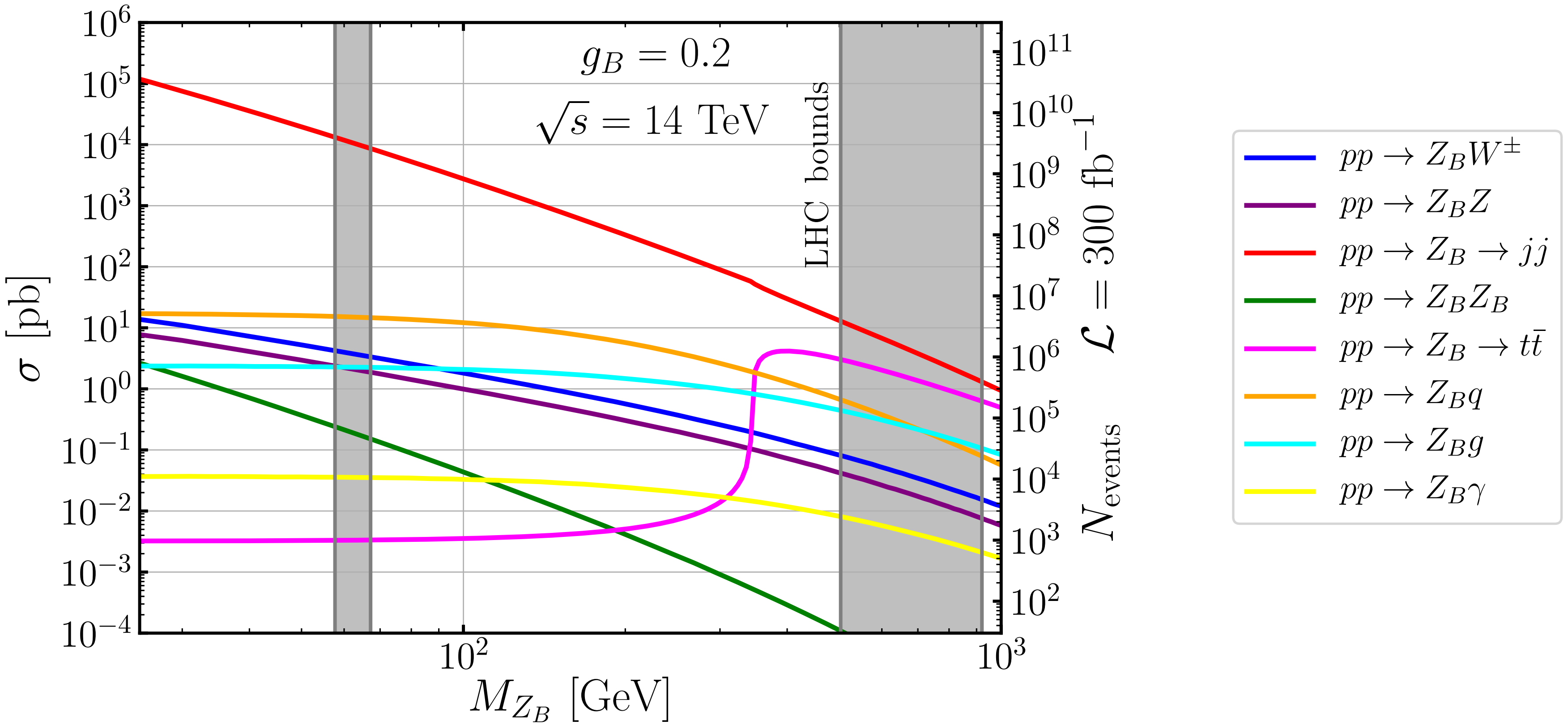
- Higgs decays can have a large branching ratios into leptophobic gauge bosons.

- Associated Higgs-Leptophobic gauge boson production mechanisms may result in the large number of events allowed at the LHC.

- The leptophobic gauge boson may exist at the low scale, and it is possible to have a simple gauge theory where baryon number is a local gauge symmetry describing physics below the TeV scale.

Thank you!

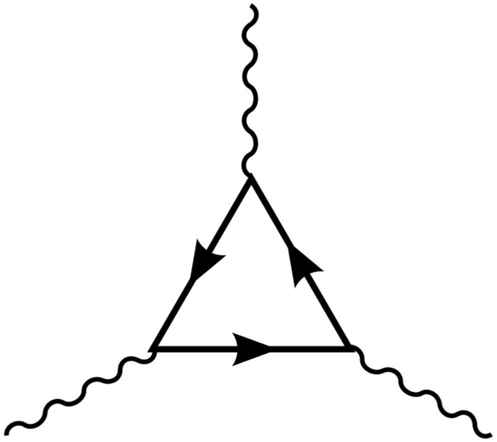
Higgs-Leptophobic Gauge Boson Associated Production



Anomaly Cancellation

- Baryonic anomalies:

$$\mathcal{A}_1(SU(3)^2 \otimes U(1)_B)$$
$$\mathcal{A}_2(SU(2)^2 \otimes U(1)_B)$$
$$\mathcal{A}_3(U(1)_Y^2 \otimes U(1)_B)$$
$$\mathcal{A}_4(U(1)_Y \otimes U(1)_B^2)$$
$$\mathcal{A}_5(U(1)_B)$$
$$\mathcal{A}_6(U(1)_B^3)$$

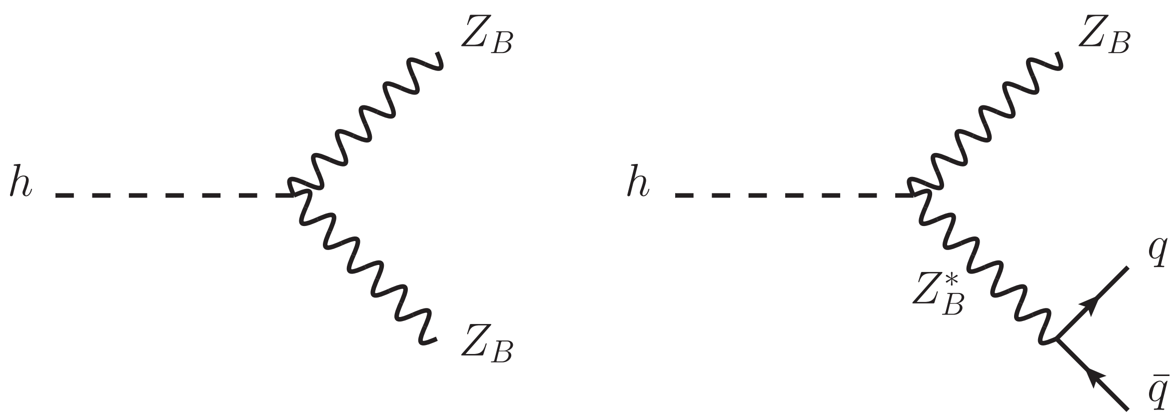


$$\mathcal{A}_2^{\text{SM}} = -\mathcal{A}_3^{\text{SM}} = 3/2 \neq 0$$

- Nonzero anomalies require additional particle content.

P. Fileviez Perez, *New Paradigm for Baryon and Lepton Number Violation*, Phys. Rept. 597 (2015) 1-30

Decay Widths: Higgs Boson



$$\Gamma(h \to Z_B Z_B) = \frac{G_B M_h^3 \sin^2\theta_B}{16\sqrt{2}\pi}\sqrt{1-4x}\left(1-4x+12x^2\right)$$

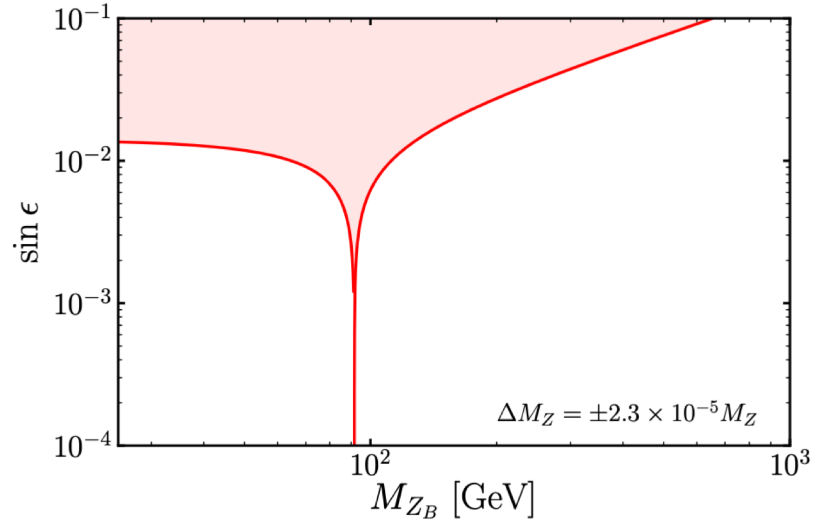
$$\Gamma(h \to Z_B q\bar{q}) = \frac{1}{(2\pi)^3}\frac{1}{32 M_h^3}\int_{p_{12}^{\min}}^{p_{12}^{\max}} dp_{12}\int_{p_{23}^{\min}}^{p_{23}^{\max}} dp_{23}\;\left|\overline{A}(h \to \bar{q}q Z_B)\right|^2$$

$$\left|\overline{A}(h \to \bar{q}q Z_B)\right|^2 = \frac{8}{3}\frac{g_B^2}{v_B^2}\frac{M_{Z_B}^4 \sin^2\theta_B}{\left((p_{23}-M_{Z_B}^2)^2 + M_{Z_B}^2\Gamma_{Z_B}^2\right)} \times \left(p_{23} + \frac{(p_{12}-M_{Z_B}^2)(M_h^2 - p_{12} - p_{23})}{M_{Z_B}^2}\right)$$

$$p_{12}^{\min} = M_{Z_B}^2, \quad p_{12}^{\max} = M_h^2,$$
$$p_{23}^{\min} = 0, \quad p_{23}^{\max} = \frac{1}{p_{12}}(p_{12}-M_{Z_B}^2)(M_h^2 - p_{12})$$

Constraints from Kinetic Mixing

$$\mathcal{L} \supset -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} - \frac{1}{2}\mathrm{Tr}\ W_{\mu\nu}W^{\mu\nu} - \frac{1}{4}B'_{\mu\nu}B'^{\mu\nu} - \frac{\sin\epsilon}{2}B_{\mu\nu}B'^{\mu\nu}$$
$$+ \frac{1}{8}(g_2 W_{3\mu} - g_1 B_\mu)(g_2 W_3^\mu - g_1 B^\mu)v_0^2 + \frac{1}{2}\mu_{B'}^2 B'_\mu B'^\mu$$
$$- \sum_i \overline{\psi}_i \gamma^\mu \left[g_1(Y_L^i P_L + Y_R^i P_R)B_\mu + g_2 P_L T^a W_{a\mu}\right]\psi_i + g_B \sum_i \overline{\psi}_i \gamma^\mu Q_B \psi_i B'_\mu$$



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