Dark Matter From Anomaly Cancellation at the LHC

Hridoy Debnath

Department of Physics

Case Western Reserve University

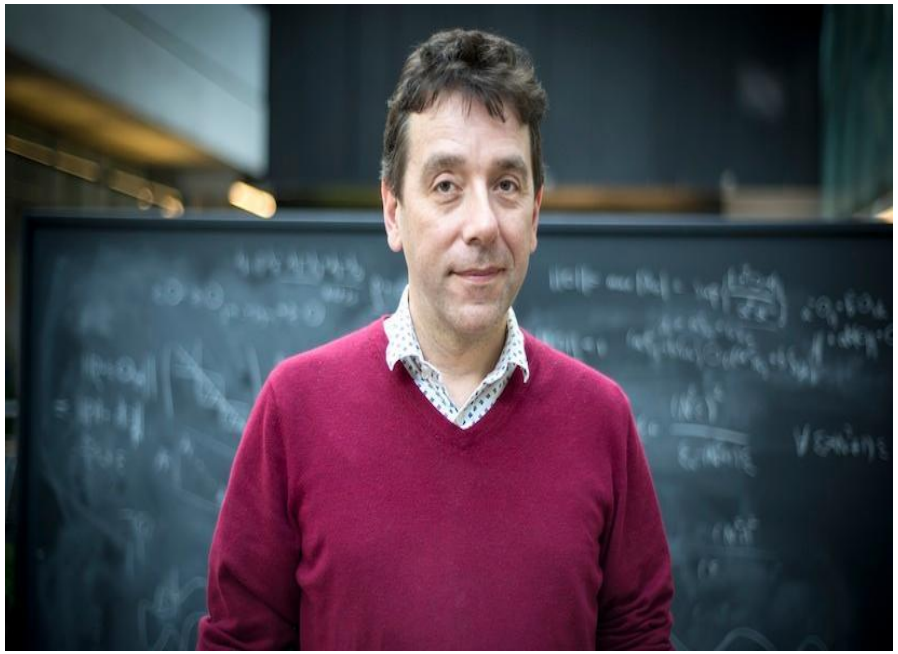
(Re)interpretation of the LHC results for new physics

CERN , 2025

Collaborators

Pavel Fileviez Pérez

Case Western Reserve University



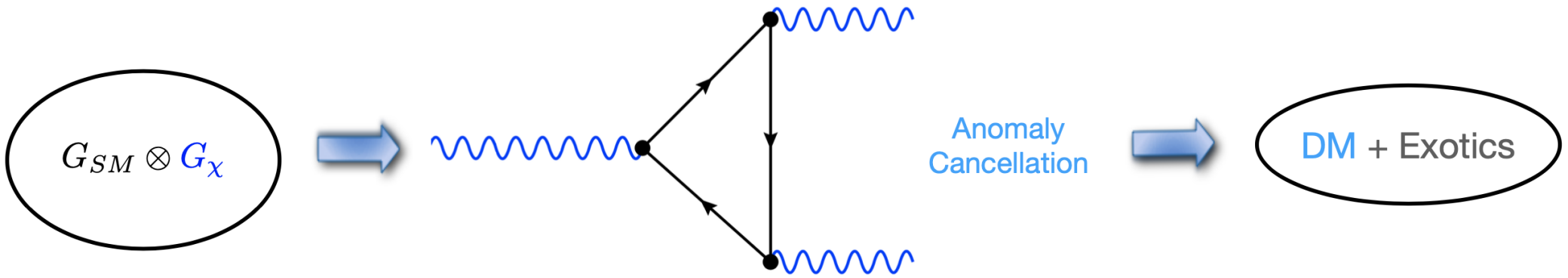
Jonathan Butterworth

University College London

Yoran Yeh

University College London

Motivation



G_χ

a) Lepton Number

b) Baryon Number

Anomalies

$$SU(3)_C \times SU(2)_L \times U(1)_Y \times U(1)_B$$

$$\mathcal{A}\left(SU(3)_c^2 U(1)_B\right) = 0$$

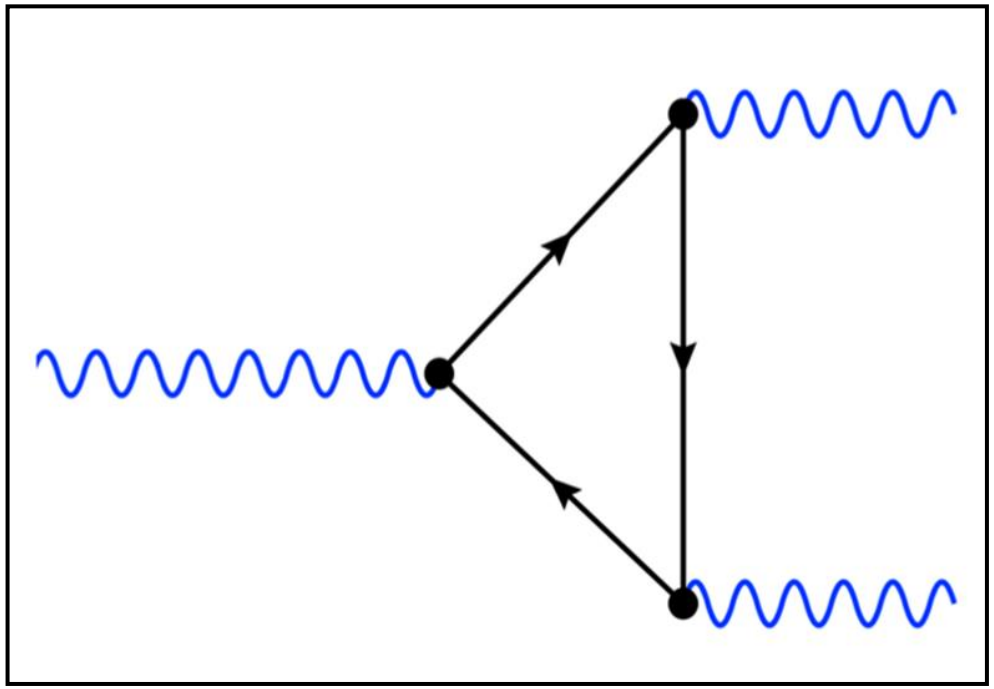
$$\mathcal{A}\left(SU(2)_L^2 U(1)_B\right) = 3/2$$

$$\mathcal{A}\left(U(1)_Y^2 U(1)_B\right) = -3/2$$

$$\mathcal{A}\left(U(1)_Y U(1)_B^2\right) = 0$$

$$\mathcal{A}\left(U(1)_B^3\right) = 0$$

$$\mathcal{A}\left(U(1)_B\right) = 0$$



P.Fileviez.Perez and M.B.Wise ,Phys.Rev.D 82 (2010) 079901

M.Duerr, P.Fileviez.Perez and M.B.Wise ,Phys.Rev.Lett. 110 (2013) 231801

Solutions to cancel Anomalies

1) Minimal Model :

P.Fileviez Perez, Phys.Rev.D 110 035018(2024)

$$\Psi_L \sim (1,1,-1,3/4) \qquad \chi_L \sim (1,1,0,3/4)$$

$$\Psi_R \sim (1,1,-1,-3/4) \qquad \rho_L \sim (1,3,0,-3/4)$$

2) Four Fermionic Representations:

$$\Psi_L \sim (1,2,1/2,3/2) \qquad \Psi_R \sim (1,2,1/2,-3/2)$$

$$\Sigma_L \sim (1,3,0,-3/2) \qquad \chi_L \sim (1,1,0,-3/2)$$

P.Fileviez Perez , S.Ohmer , H.H.Patel ,Phys.Lett. B735, 283

Dark Matter and Local Baryon Number

In these theories one has the following interactions:

$$\mathcal{L} \supset -\tfrac{g_B}{3}\bar{q}\gamma^\mu q Z_\mu^B + (D_\mu S_B)^\dagger (D^\mu S_B) + i\bar{\chi}_L \gamma^\mu D_\mu \chi_L - V(H, S_B) + (\lambda_\chi \chi_L^T C \chi_L S_B \ \ + \text{h.c.})$$

- New gauge boson Z_B associated with the local Baryon number.
- SM like Higgs boson, $h = h_0 \cos\theta_B - h_B \sin\theta_B$
- New CP even Higgs boson, $h_B = h_0 \sin\theta_B + h_S \cos\theta_B$
- Dark Matter Candidate, χ

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Collider Bounds

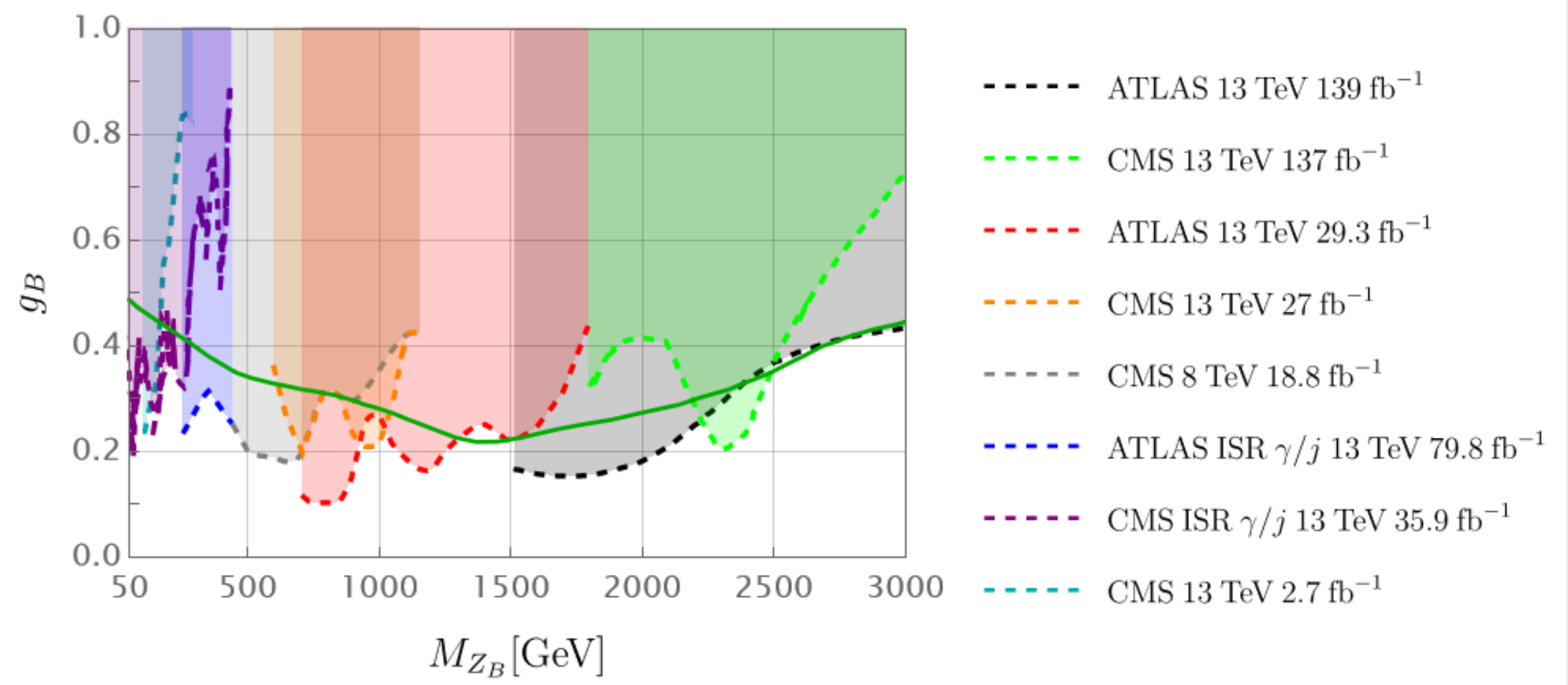

Fig. Current collider bounds on the leptophobic Z_B mass.

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Cucuyo Higgs(h_B) Decay

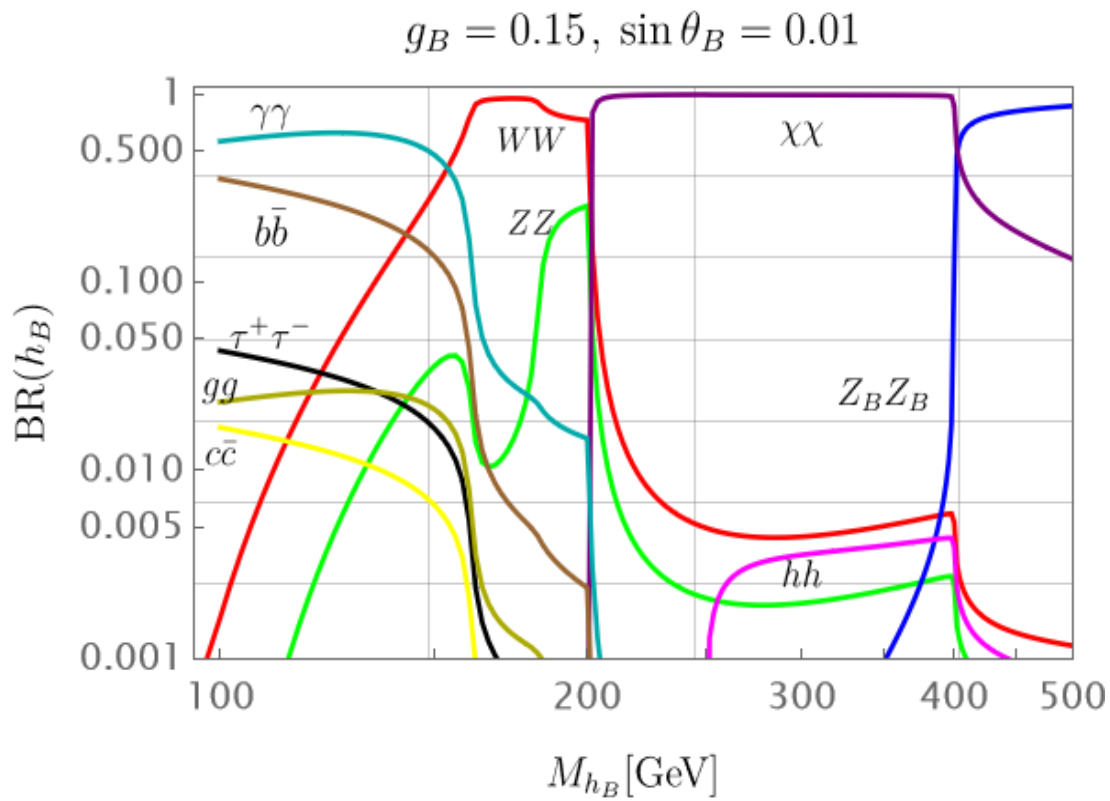


Fig. Branching ratios of h_B decays.

Cucuyo ,an insect very common in Cuba, Brazil, Guiana and Mexico. It may be seen at night in great numbers among the foliage of trees. They sometimes are so numerous that they light up the dark forest.

LHC Signatures and Constraints

- Dijet Production:

$$q\bar{q} \to Z_B^* \to jj, t\bar{t}$$

- Missing Energy Signatures:

  Monojet : $q\bar{q} \to gZ_B^* \to g\chi\chi, gq \to qZ_B^* \to q\chi\chi, g\bar{q} \to \bar{q}Z_B^* \to \bar{q}\chi\chi$

  Associated Production: $q\bar{q} \to Z_B h_B \to \chi\chi b\bar{b}, \chi\chi t\bar{t}, ...$

CONTUR Workflow

Sampling Model Parameters (contur batch)

↓

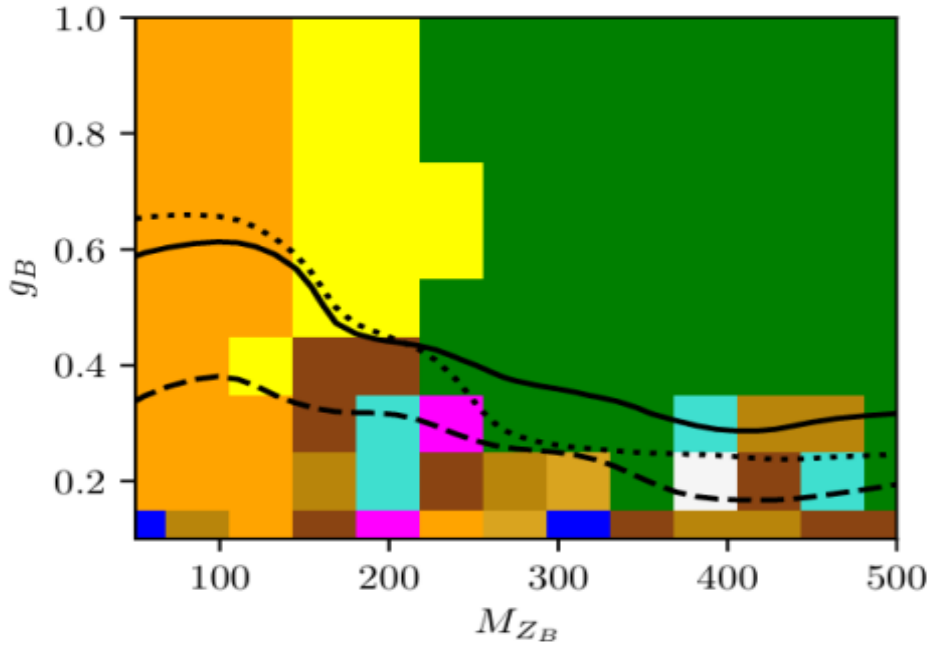
Calculate Observables (event generators , Rivet ,..)

↓

Evaluting the likelihood for a model (contur)

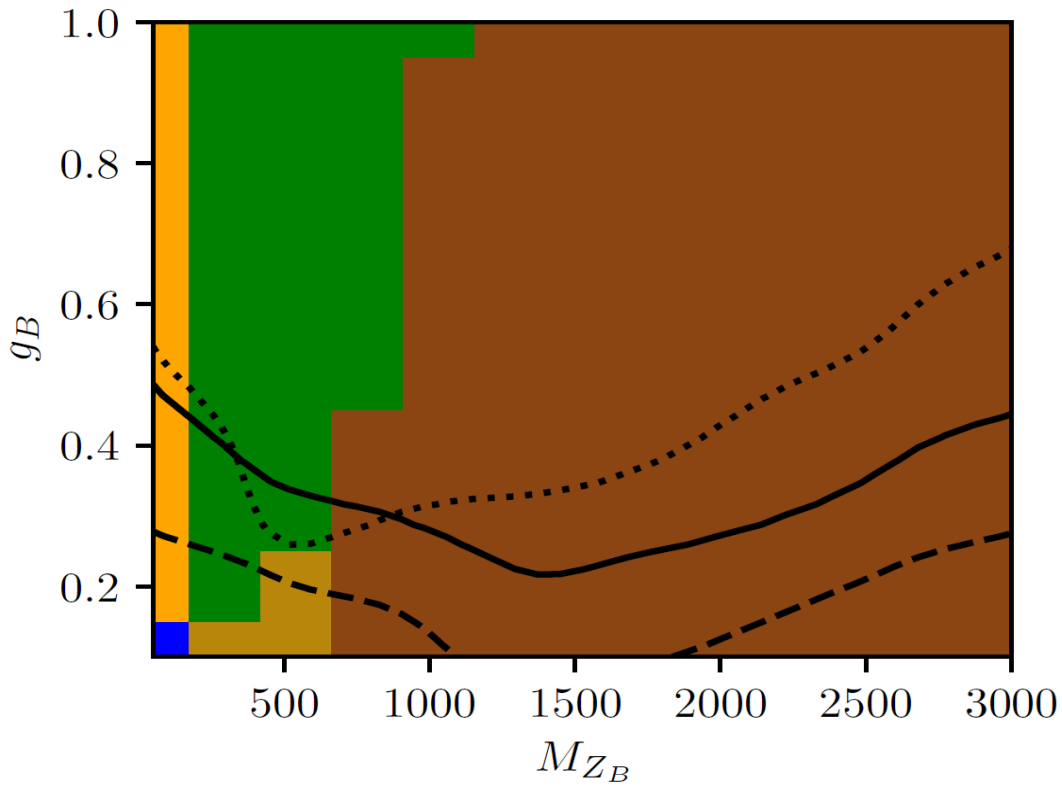
↓

Visualisation of the parameter space (Contur Plot , ...)



A.Buckley et al, SciPost Phys.Core 4, 013(2021)

Bounds on g_B



Here we assumed $M_\chi = 100$ GeV and $M_{h_B} = 200$ GeV.

95% actual exclusion : Black solid line

95% expected exclusion : Black dotted line

68% exclusion : Black dashed line

Monojet Signatures

hadronic $t\bar{t}$ | E_T^{miss}+jet | $\gamma+E_T^{\text{miss}}$ | $\ell_1\ell_2+E_T^{\text{miss}}$+jet

jets | $\ell+E_T^{\text{miss}}$+jet | $\ell^+\ell^-$+jet | $\ell^+\ell^-\gamma$

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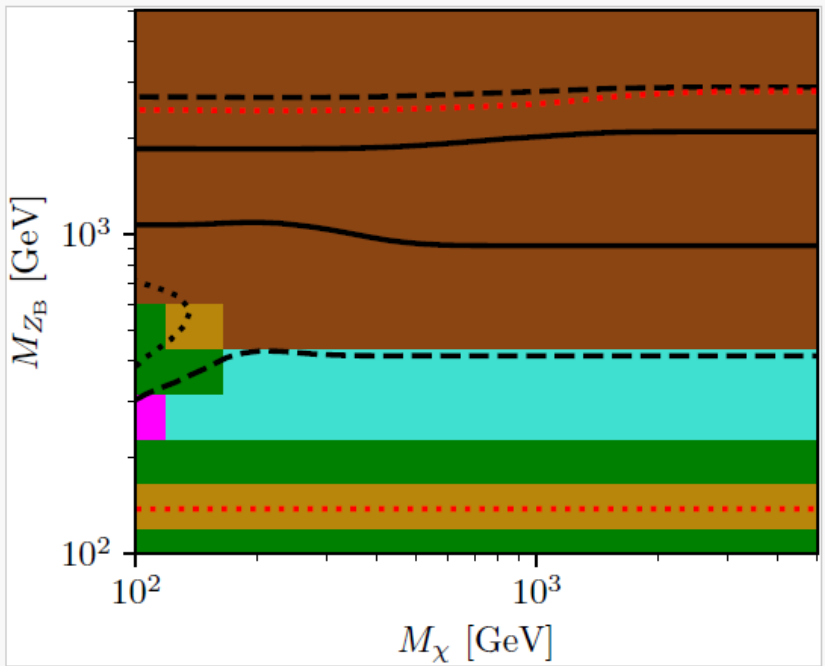
Collider Searches



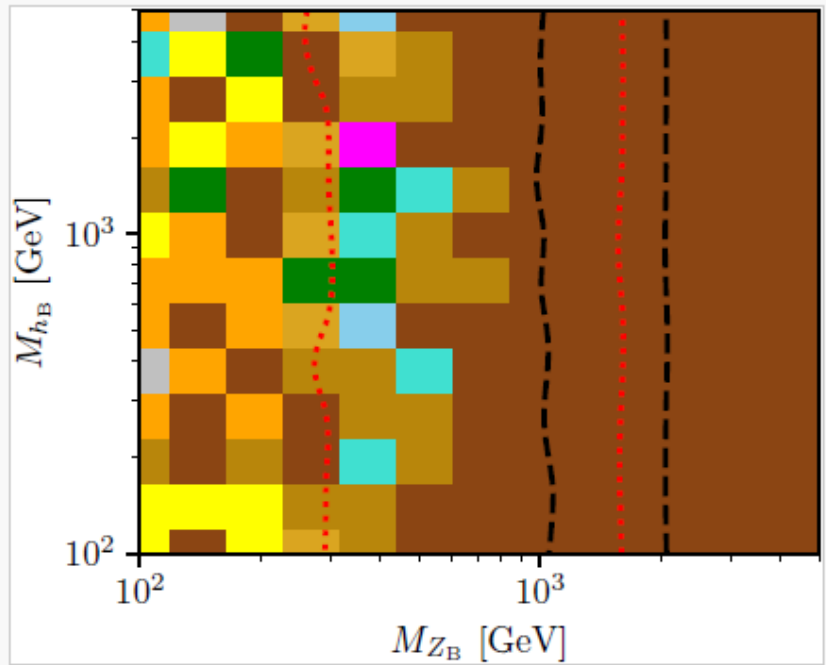


Fig. Dominant signatures in different region of parameter space.

γ
$\gamma+p_T^{\text{miss}}$
$\ell^+\ell^-\gamma$
hadronic $t\bar{t}$
$\ell+p_T^{\text{miss}}+\text{jet}$
$\ell_1\ell_2+p_T^{\text{miss}}+\text{jet}$
$p_T^{\text{miss}}+\text{jet}$
$\ell^+\ell^-+p_T^{\text{miss}}$
jets
$\ell^+\ell^-+\text{jet}$
$\ell_1\ell_2+p_T^{\text{miss}}$
4ℓ

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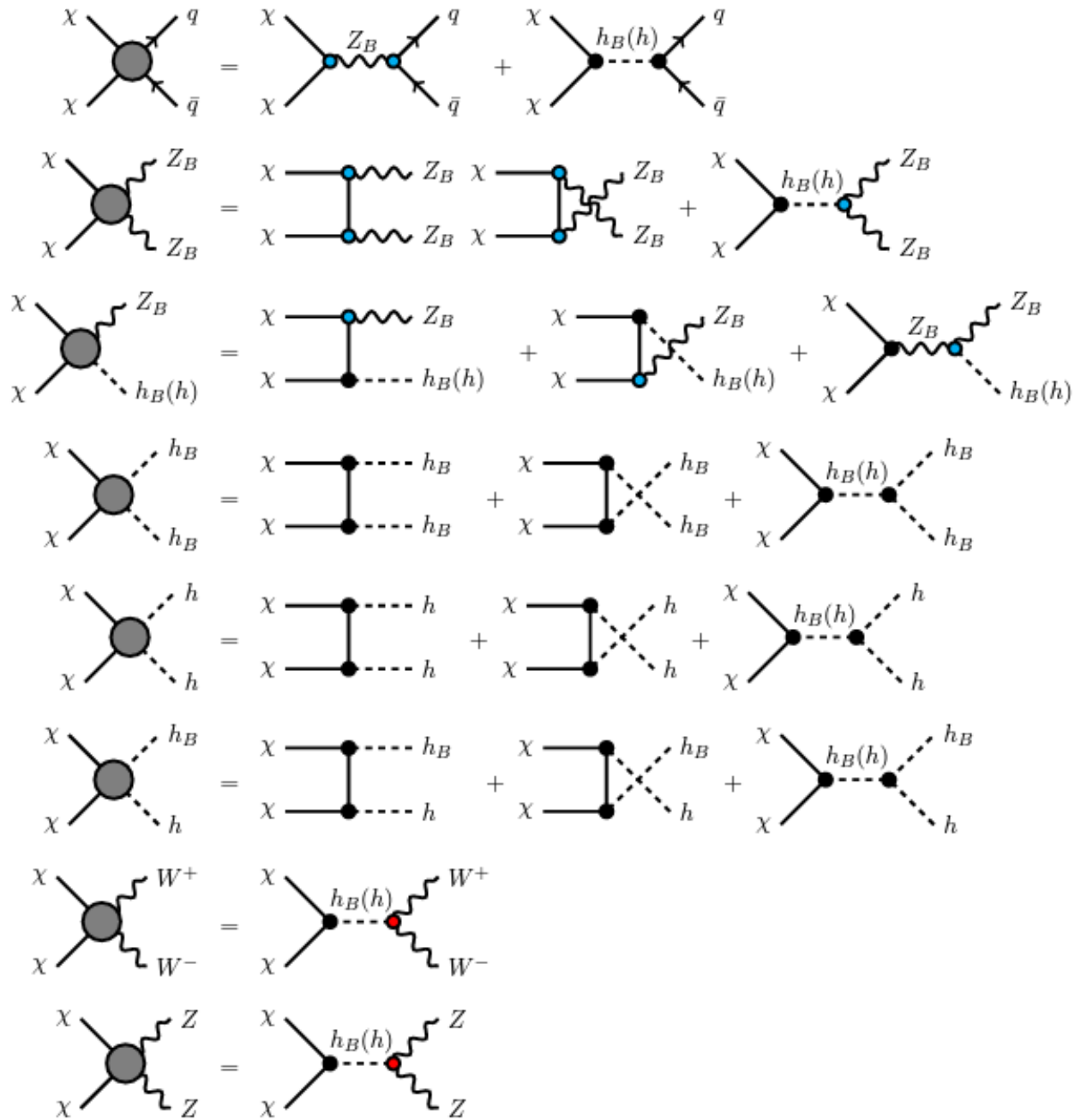
Dark Matter Constraints



Relic Density Constraint

Symmetry breaking scale is order of

$O(10)$ TeV.

One can hope to test this theory

in the near future (HL-LHC).

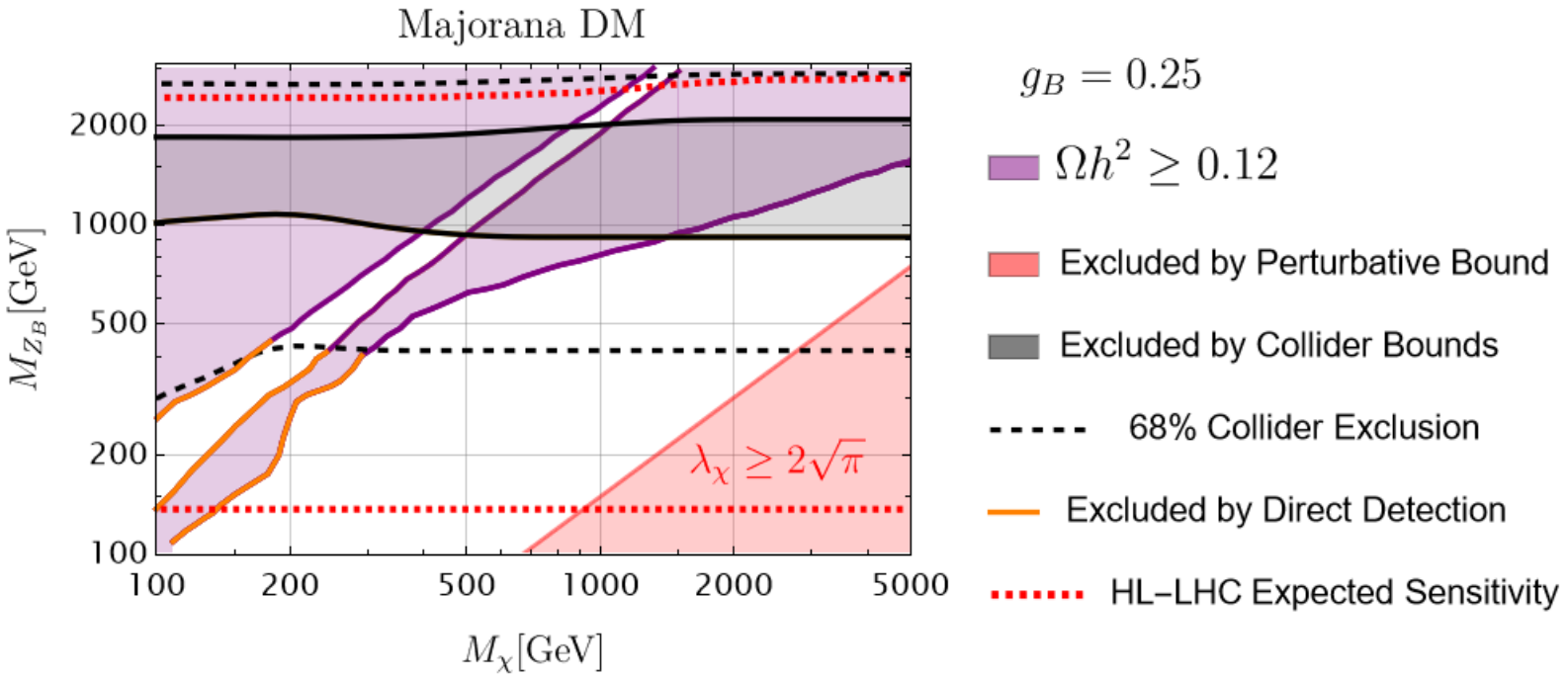


Fig. Allowed parameter space in the $M_{Z_B} - M_\chi$ plane when $g_B = 0.25$ and $M_{h_B} = 200$ GeV.

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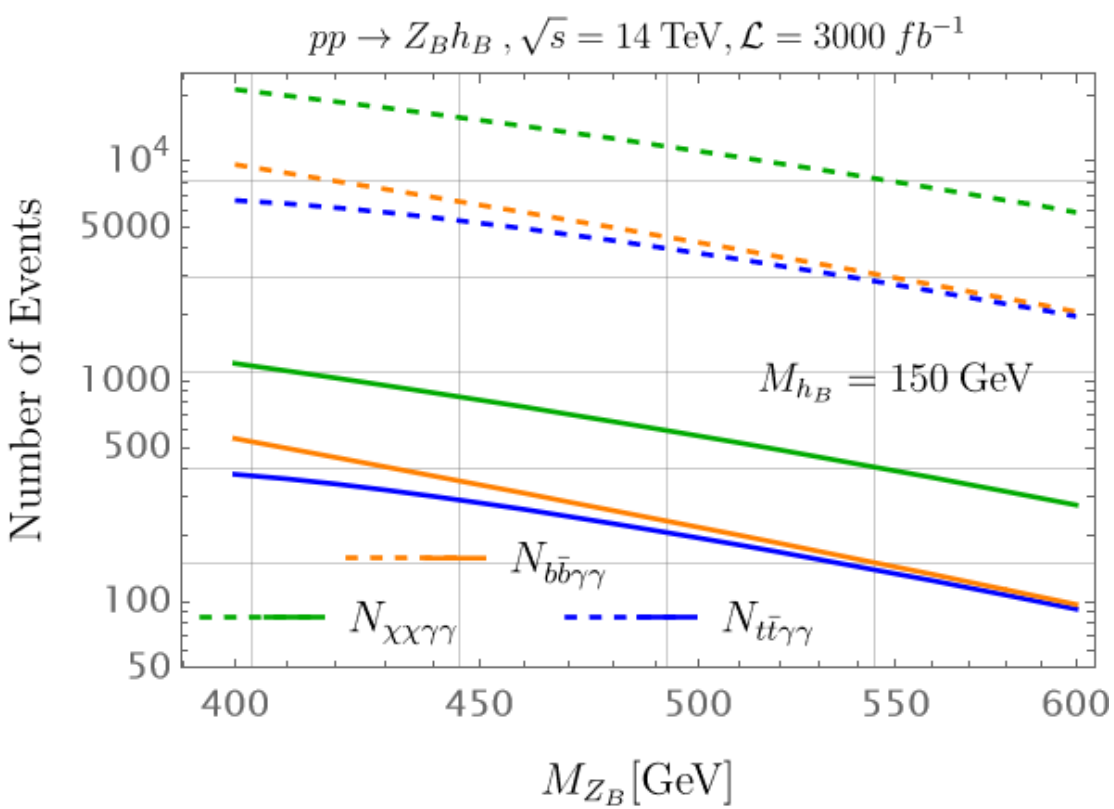
Future Prospects



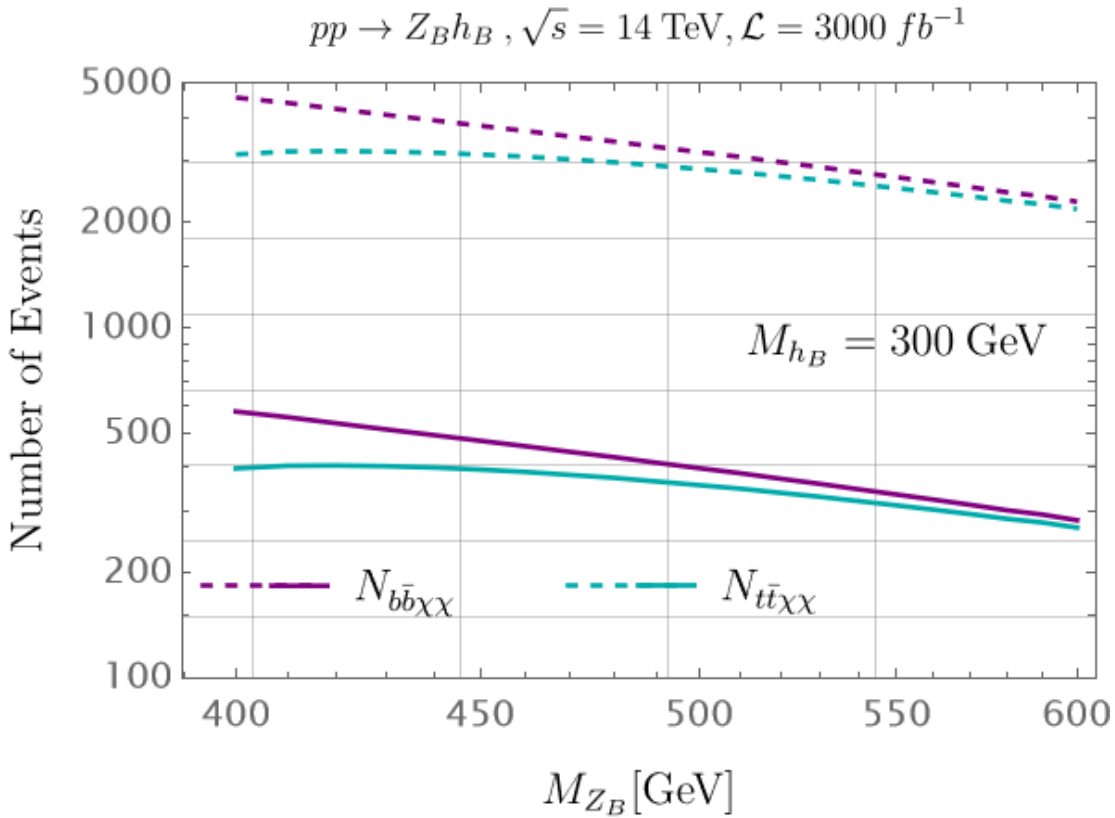


Fig. Number of events for different signatures as a function of Z_B mass.The dashed and solid lines represents the number of events for $g_B = 0.25$ and $g_B = 0.15$ respectively.

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Summary

- We discussed a class of theories where baryon number was promoted as a local gauge symmetry. In this context, Majorana dark matter is predicted from anomaly cancellation.

- We discussed the new Higgs decay in details. The new Cucuyo higgs has very interesting properties because its decay has a large branching ratio of two photons in the low mass region and if, kinematically allowed, to DM in the intermediate mass region.

- We discussed the cosmological contraints and showed that only a small fraction of parameter space is excluded by direct detection and collider searches.

- We discussed the future prospects to test this theory at the High Luminiosity upgrade of the LHC (HL-LHC).