

Dark Z' Portal

Farinaldo Queiroz

Max Planck Institute fuer Kernphysik

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Just one Goal !

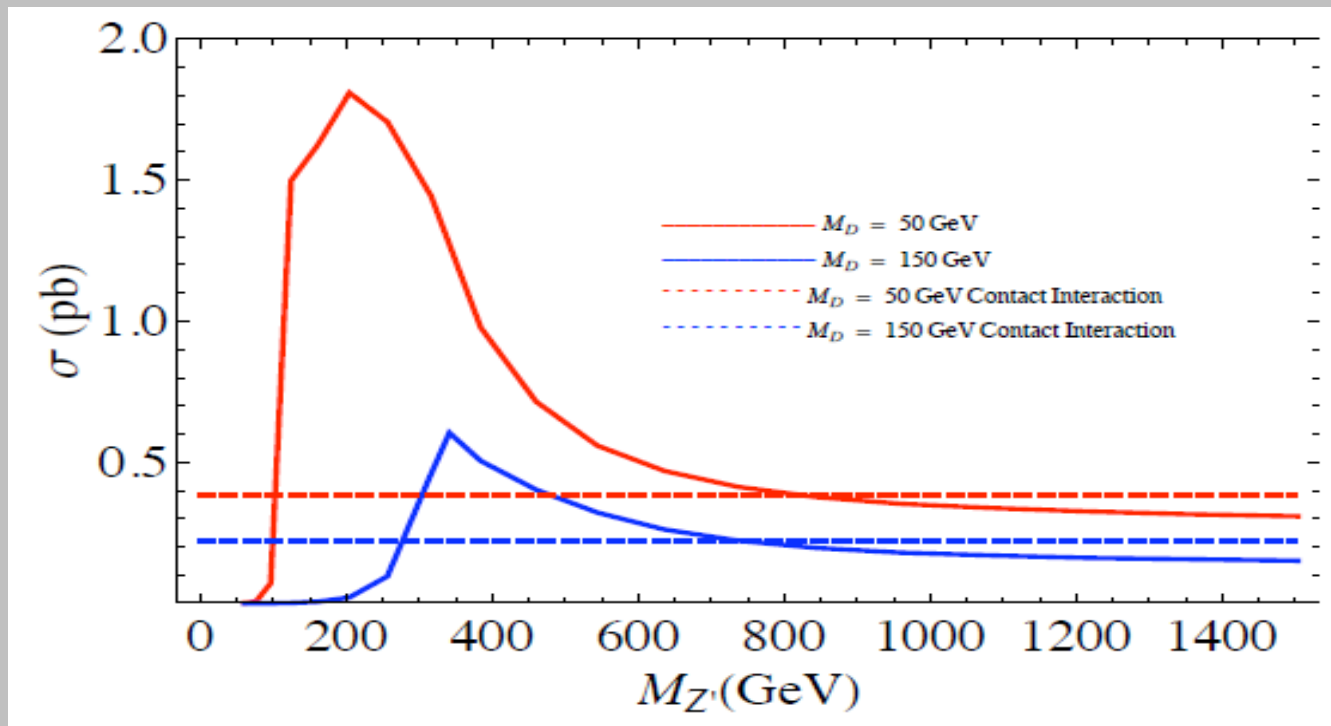
Outline the viable region of the parameter space of several U(1) gauge models

Collider Limits: Dilepton + Monojet+ Dijet

Muon Anomalous Magnetic Moment

Direct and Indirect Dark Matter Detection

Effective Operators x Simplified Model



Simplified Models provide **typically** a better description of dark matter Portals

Dark Matter in U(1) Gauge Extensions

General Idea: $U(1)$ Gauge symmetry

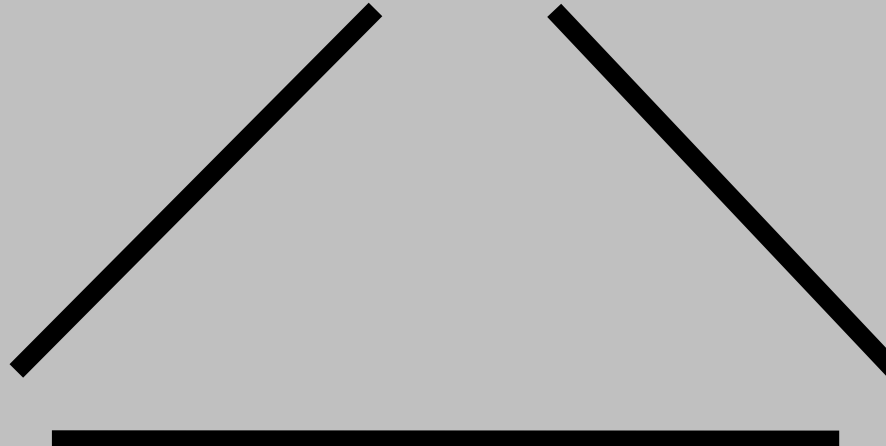


Spontaneous
Symmetry
Breaking

Massive Z'

Visible Sector

Dark Sector



General Idea: $U(1)$ Gauge symmetry



Visible Sector

Z'

Dark Sector

Different Setups

1. Leptophilic

Queiroz, Shepherd
g-2 Public Code
arxiv:1403.2309

2. Leptophobic

Queiroz, Profumo et al
arxiv:1312.5281

3. General

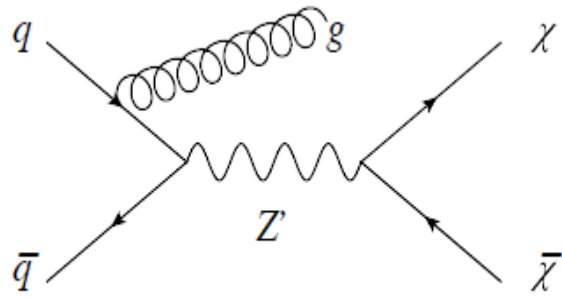
Queiroz, Profumo et al
Arxiv:1501.03490

4. $U(1)$ Gauge Structures

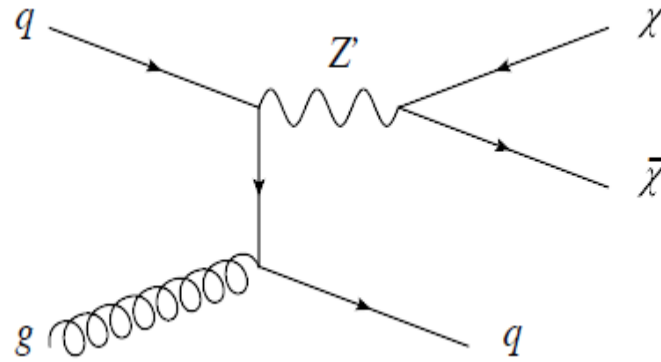
Queiroz, Profumo et al
Arxiv:1502.nextweek

Collider Limits in U(1) Gauge Extensions

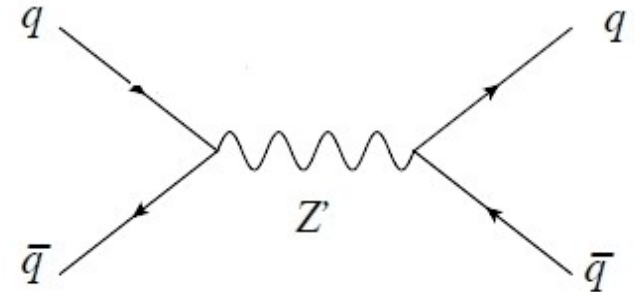
Monojet +Dijet +Dileptons



$$p\bar{p} \rightarrow Z' \rightarrow jj$$



$$pp \rightarrow Z' + j \rightarrow \chi\bar{\chi} + j \rightarrow E_T + j$$

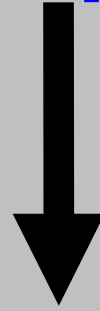


$$pp \rightarrow Z' \rightarrow jj$$

IMPORTANT LESSON:

If Z' -lepton couplings are not suppressed Dileptons searches will provide the strongest bounds

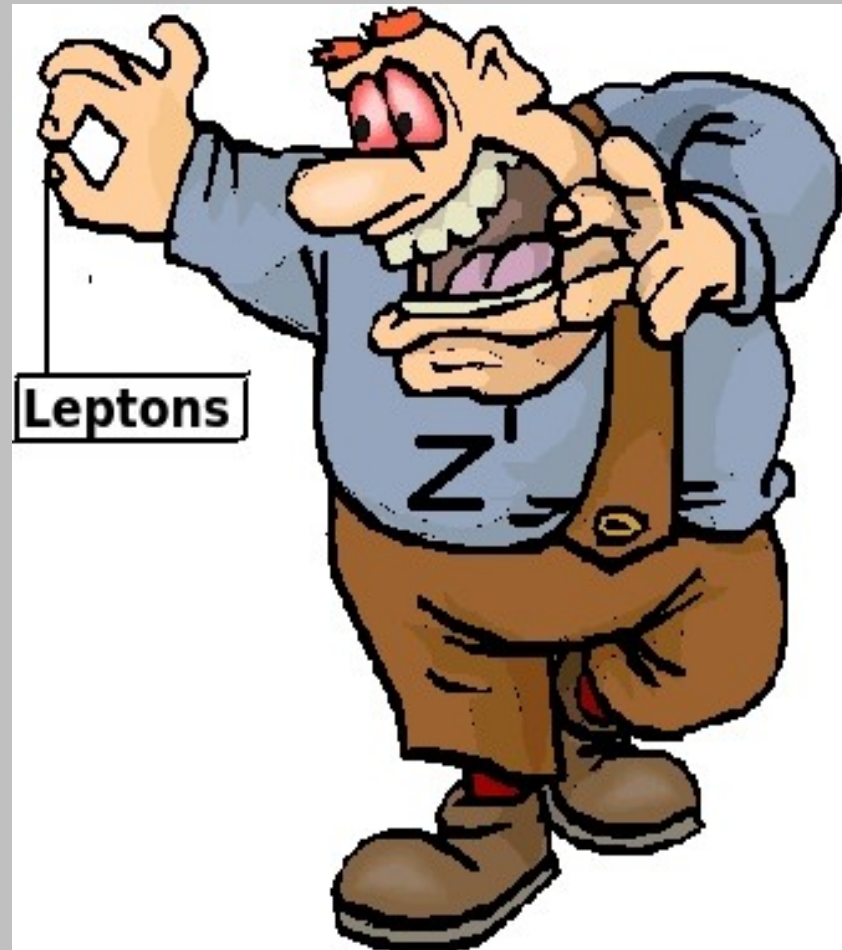
Leptophobic



Visible Sector

Z'

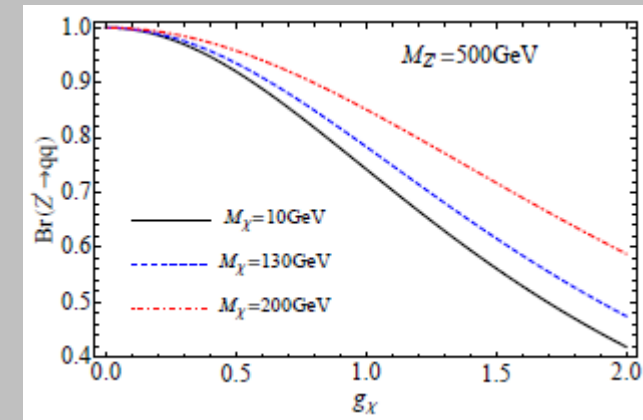
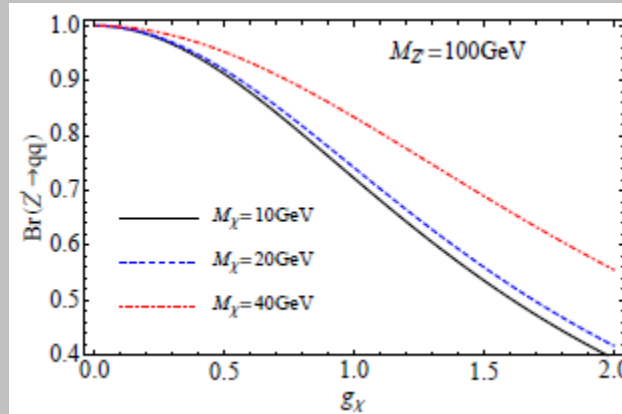
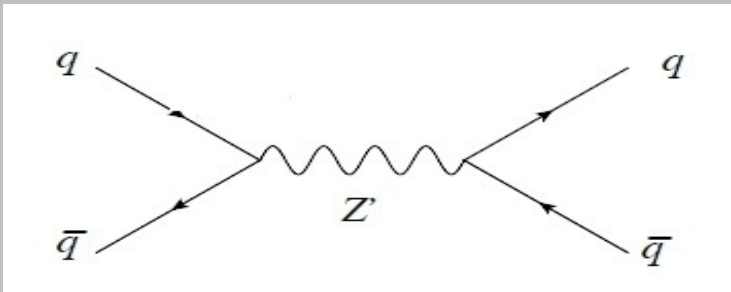
Dark Sector



Collider Bounds on Leptophobic Scenarios

$$p\bar{p} \rightarrow Z' \rightarrow jj$$

$$pp \rightarrow Z' \rightarrow jj$$



A new heavy neutral gauge boson such Z' may lead to a resonance in jj .

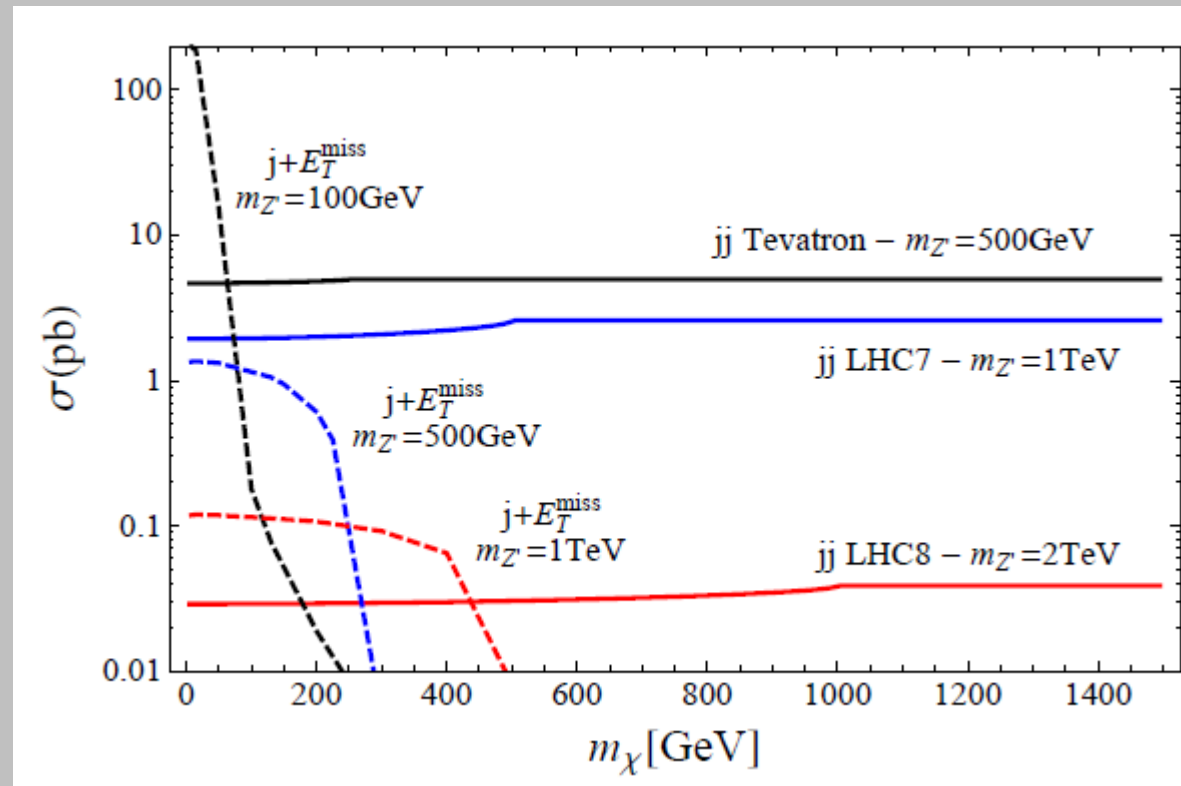
No resonance has been found

The effect of the mass and couplings of the DM particle on the dijet bounds is indirect.

For a fixed Z' mass, the branching ratio $BR(Z' \rightarrow q\bar{q})$ increases as M_χ approaches $M_{Z'}/2$, up until

$$BR(Z' \rightarrow q\bar{q}) + BR(Z' \rightarrow \chi\bar{\chi}) = 1$$

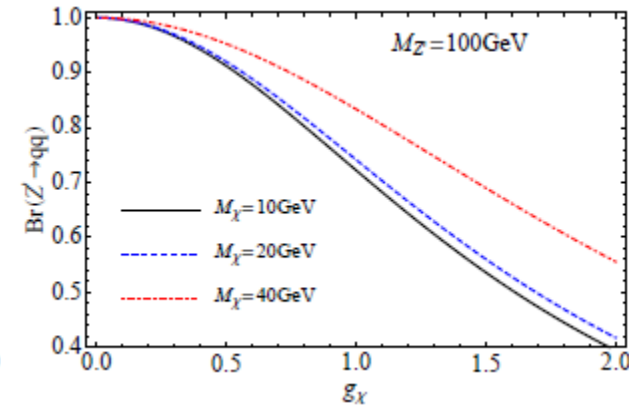
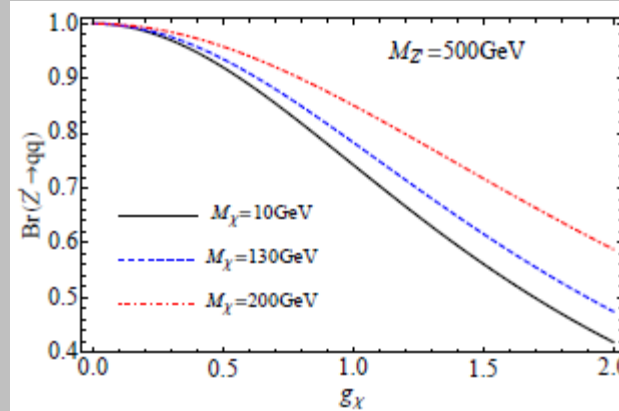
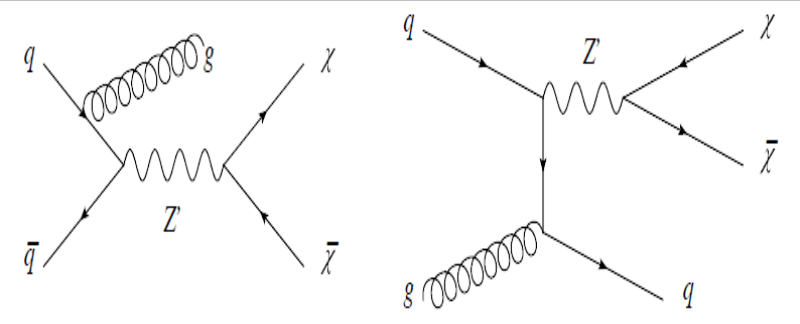
Decreasing the coupling between the DM and Z' increases the branching fraction into quarks.



Collider Bounds on Leptophobic Scenarios

Dijet + Mono-Jet Bounds

$$pp \rightarrow Z' + j \rightarrow \chi\bar{\chi} + j \rightarrow \cancel{E}_T + j$$

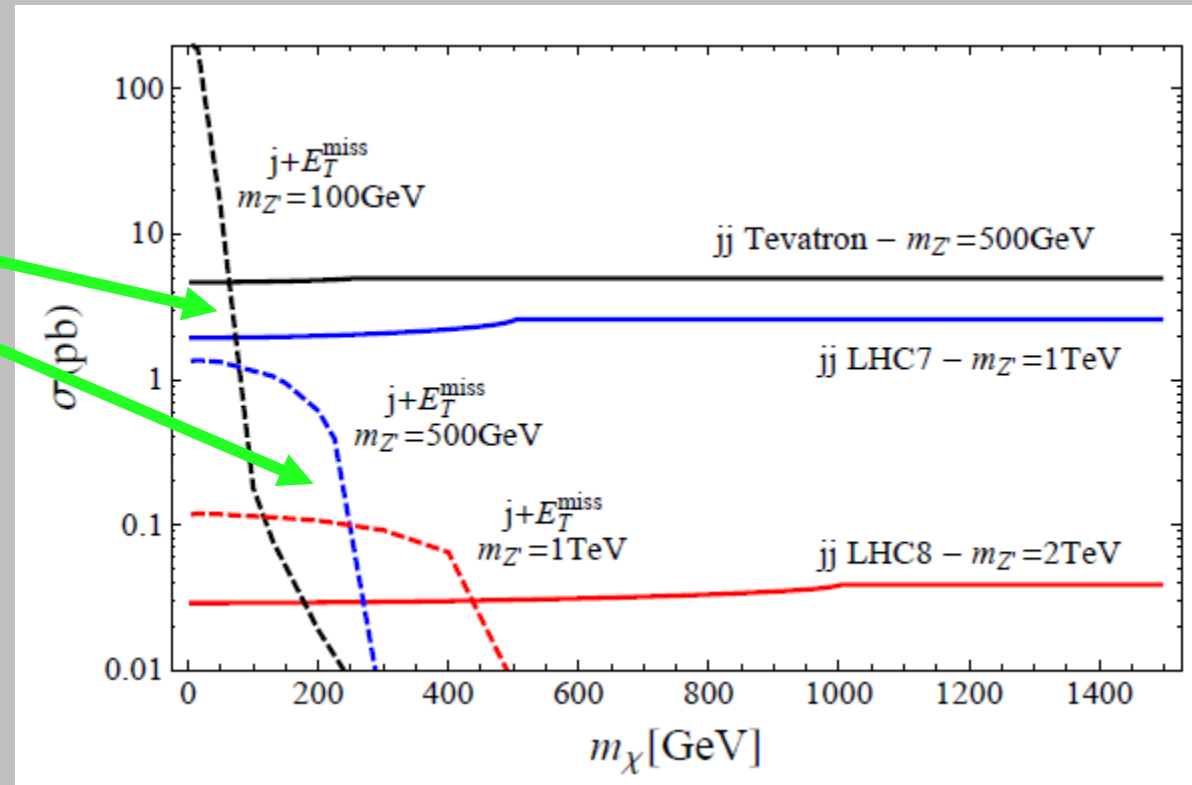


The dark matter mass and couplings are important

For a fixed Z' mass, the branching ratio $BR(Z' \rightarrow q\bar{q})$ increases as M_χ approaches $M_{Z'}/2$, up until

$$BR(Z' \rightarrow q\bar{q}) + BR(Z' \rightarrow \chi\bar{\chi}) = 1$$

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Collider Bounds on Leptophobic Scenarios

Dijet + Mono-Jet Bounds

CMS 8 TeV 19.5 fb⁻¹

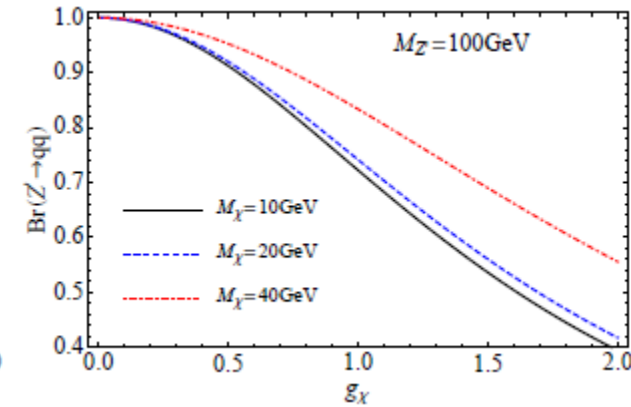
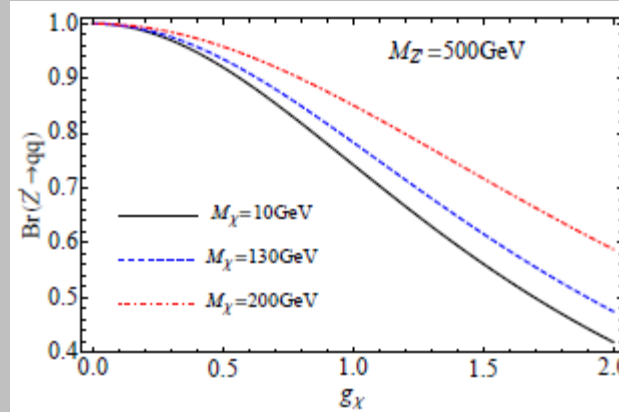
We simulated the process

$$pp \rightarrow Z' + j \rightarrow \chi\bar{\chi} + j \rightarrow \cancel{E}_T + j$$

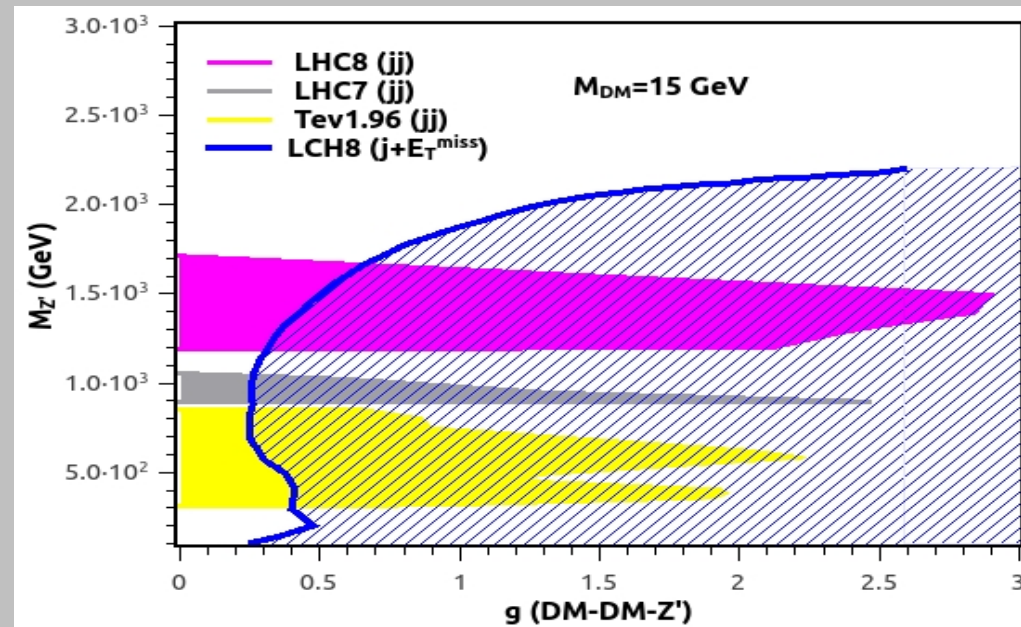
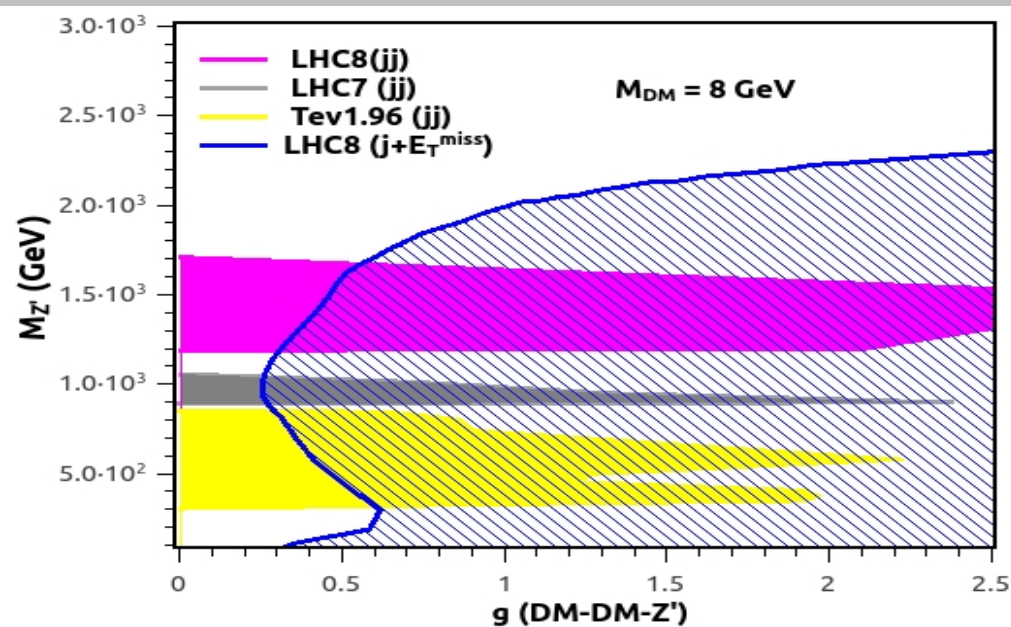
Requirements:

$P_T > 110$ GeV

Jet rapidities $y < 2.4$



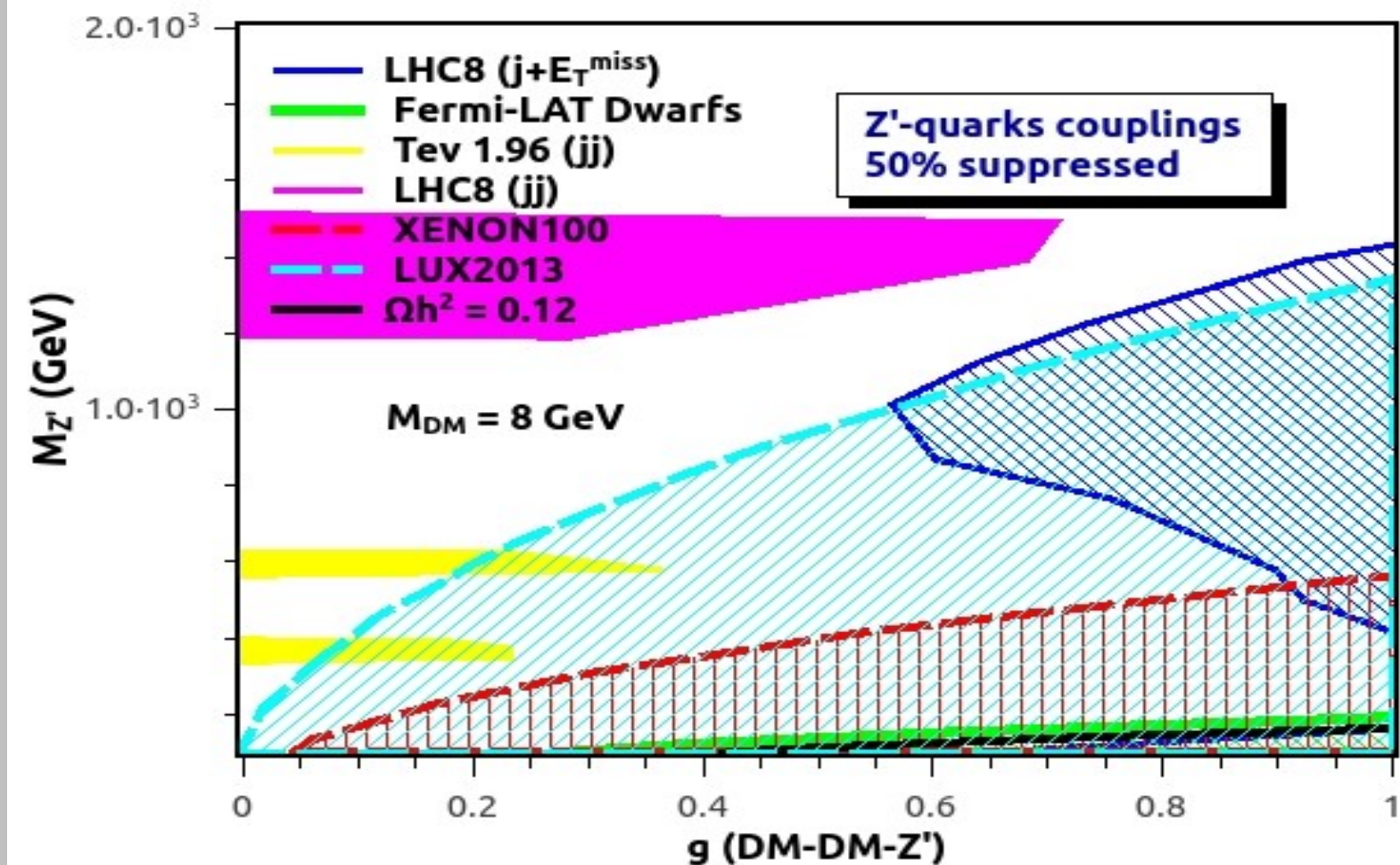
We derived 95% C.L limits for $Z' = Z$



Dark Matter Complementarity on Leptophobic Scenarios

Assuming the couplings are suppressed in 50% compared to the Z quarks ones

Note how significant the impact of suppressing the Z'-quarks couplings in 50% is



General Z'



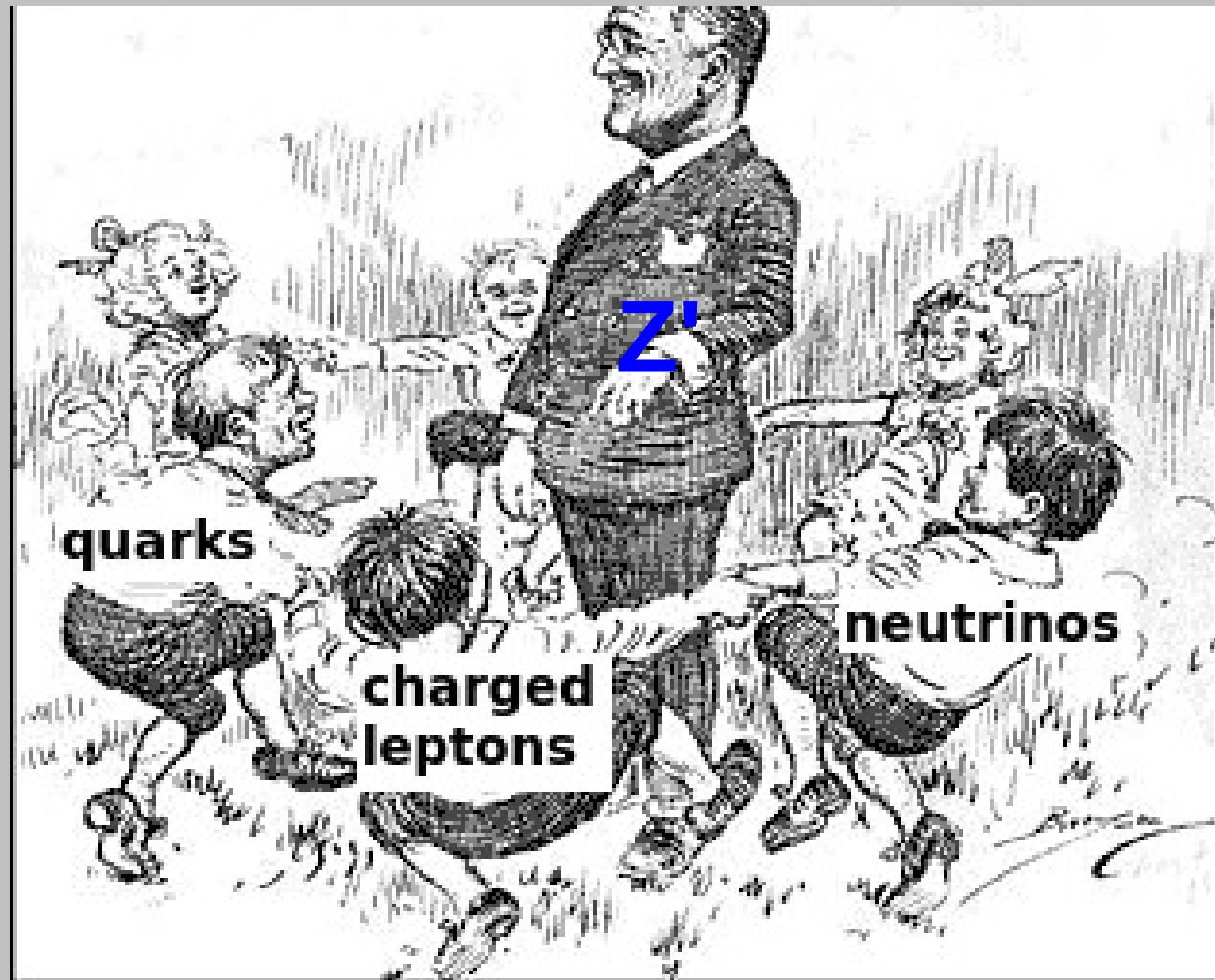
Visible Sector

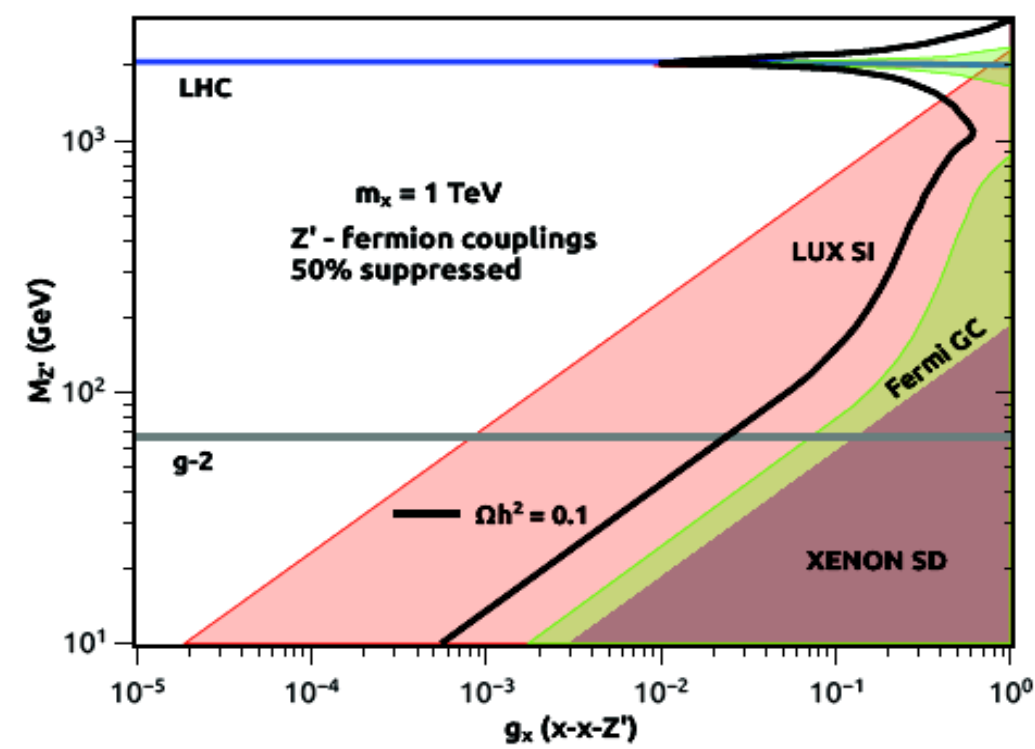
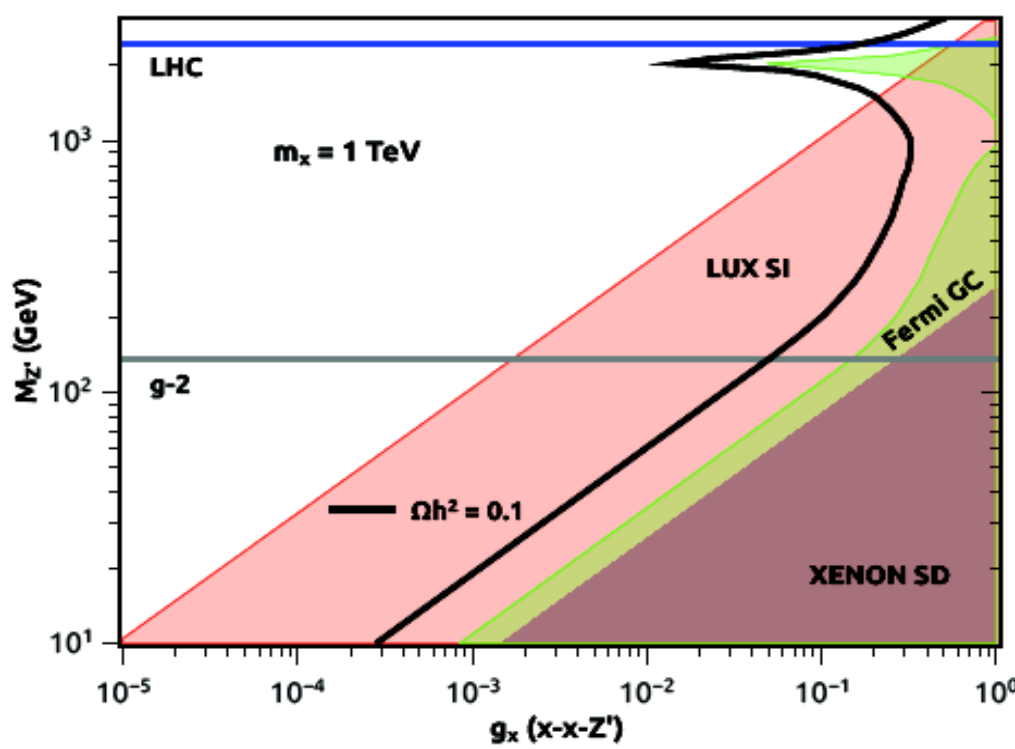
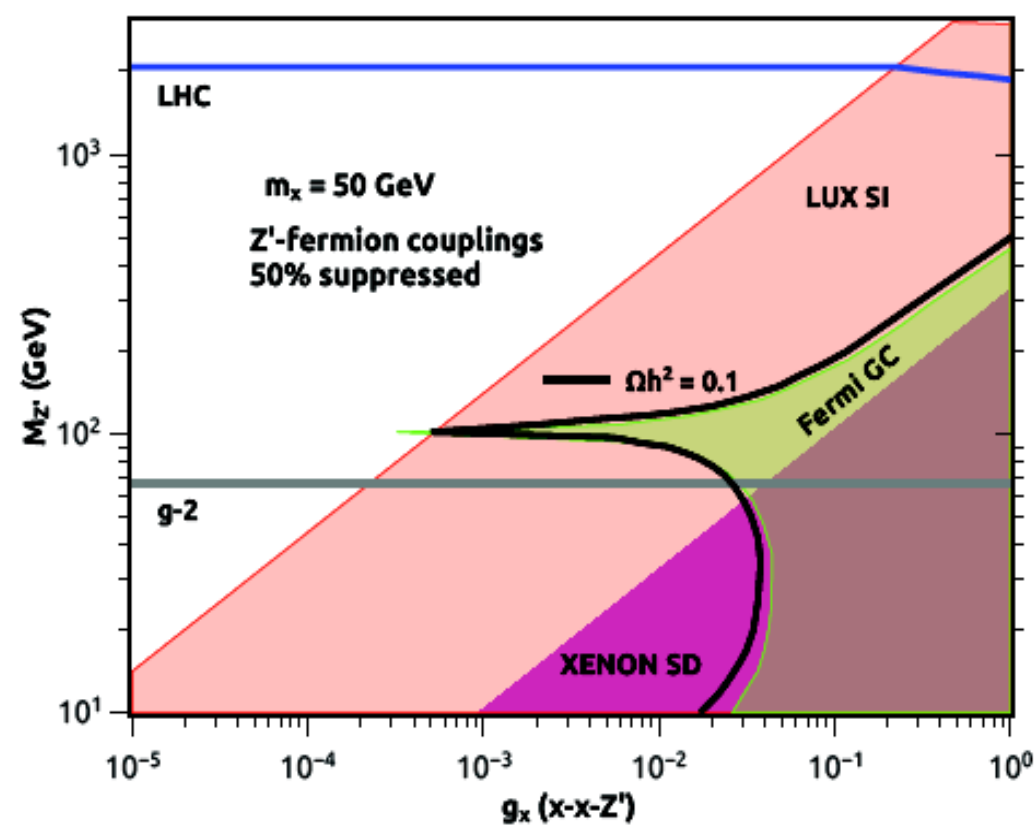
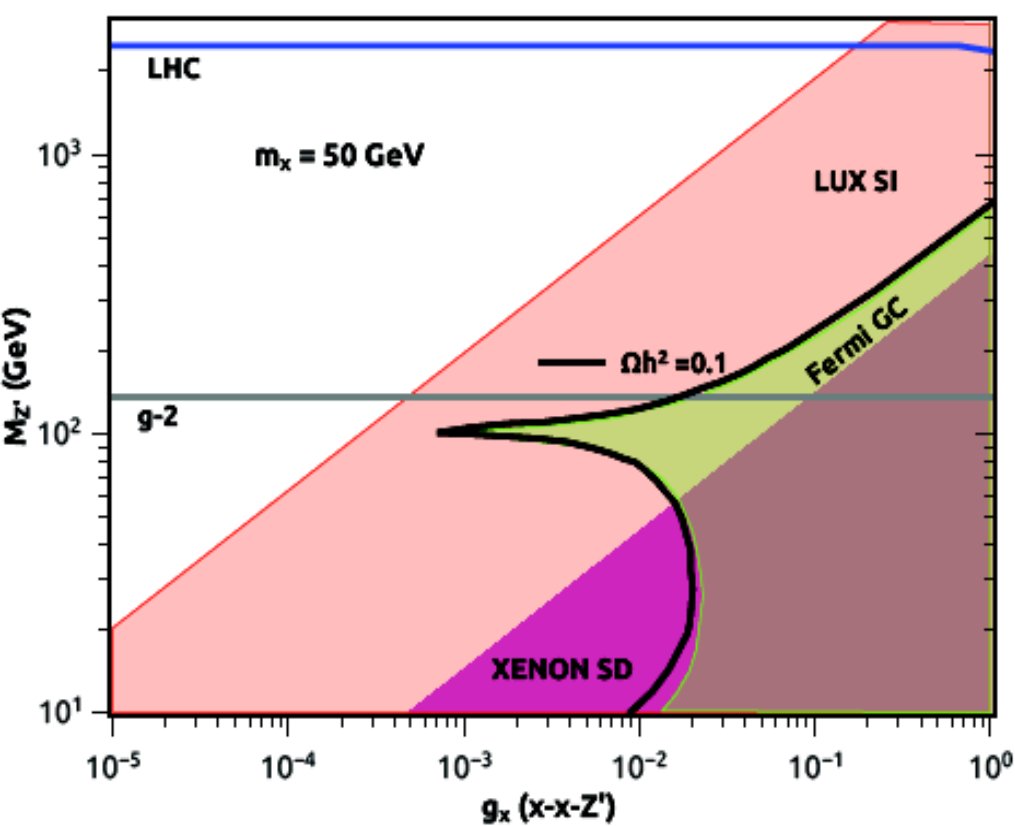
Z'

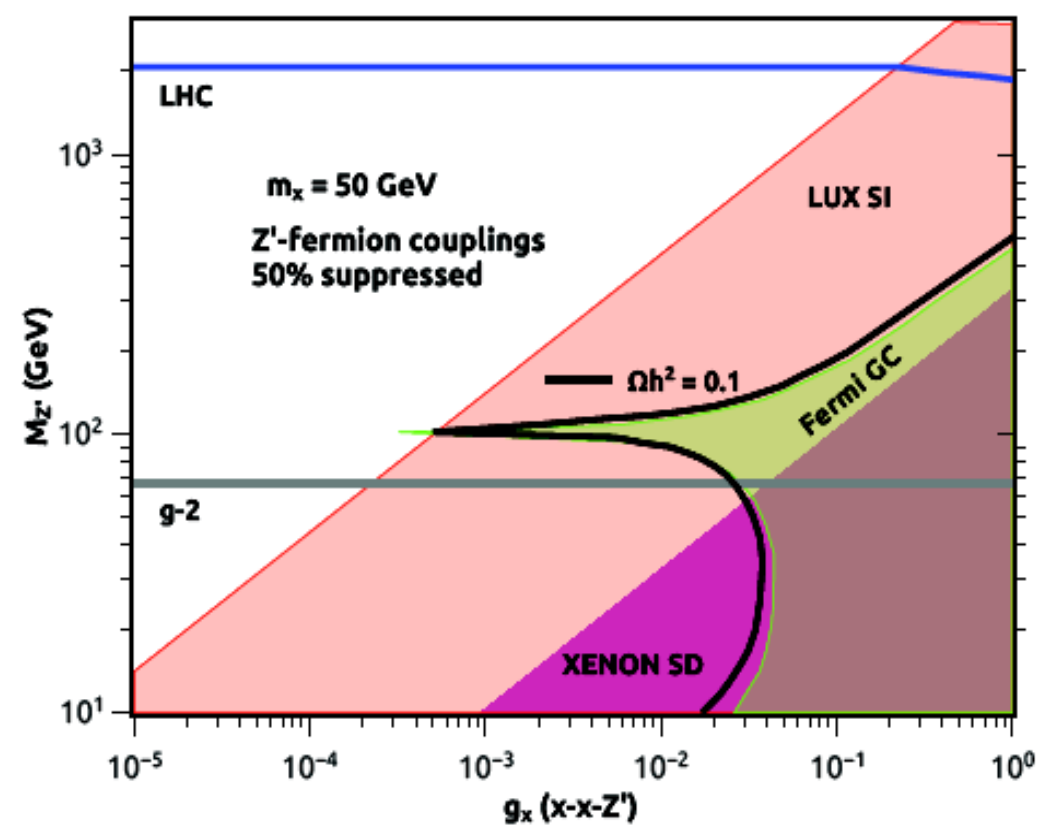
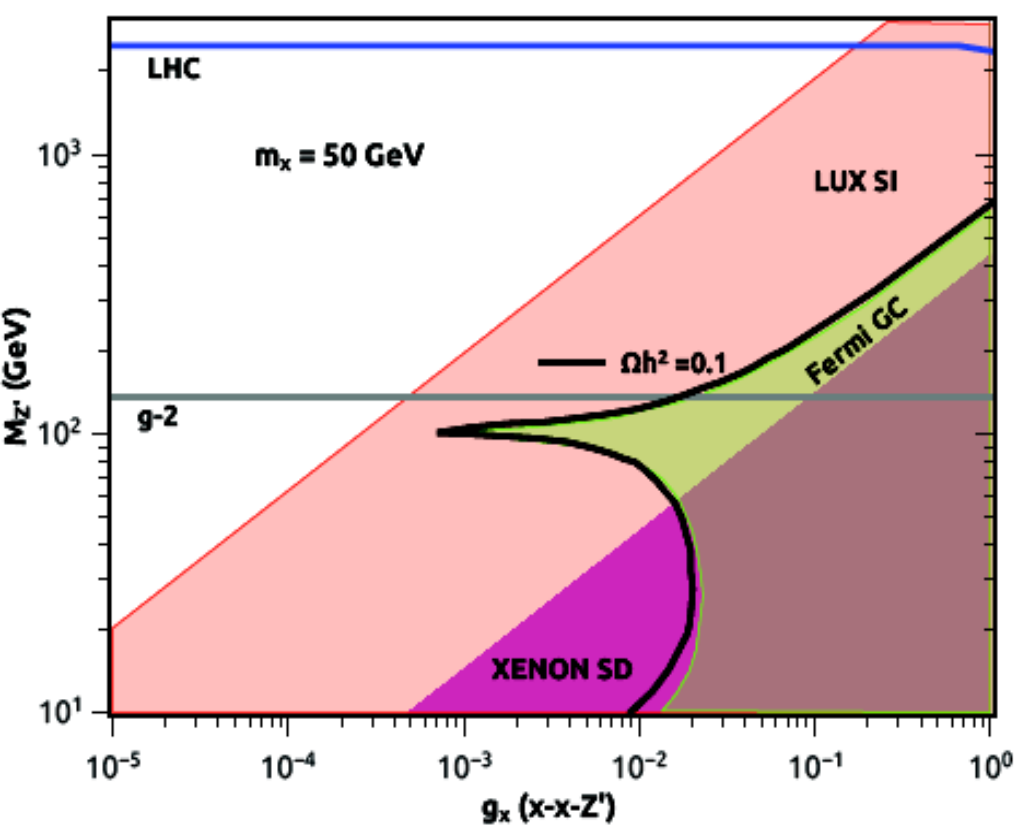
Dark Sector

Z' Interacting with all fermions

[arxiv:1501.03490](https://arxiv.org/abs/1501.03490)







Only mediators heavier than 2.1 TeV are allowed by data, implying into heavy dark matter masses (\sim TeV) to get the right abundance.

U(1) Gauge Models

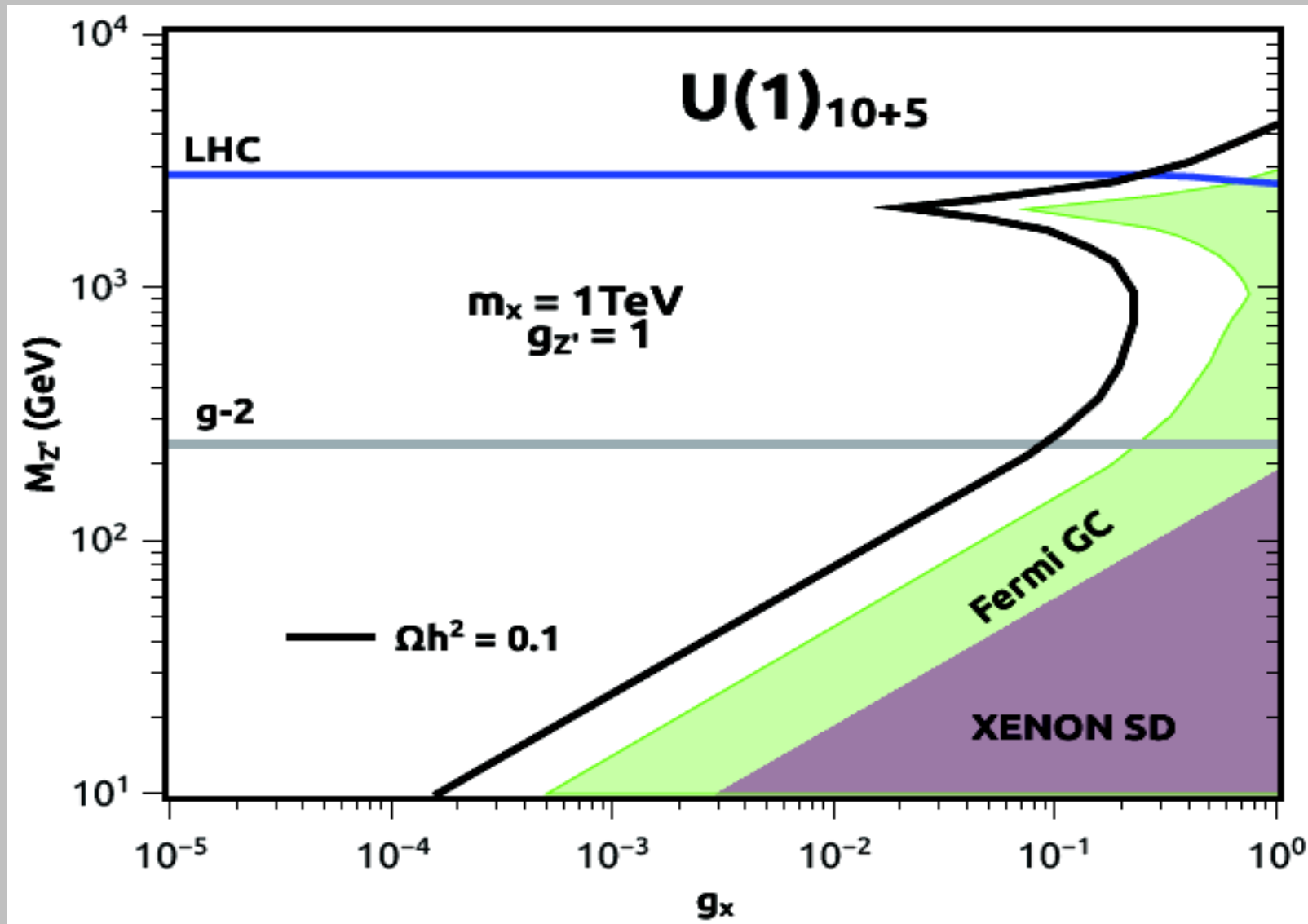
Guiding principle

1. Avoid flavor changing neutral currents at tree level
2. Allow for cancellation of triangle anomalies by the introduction of vector-like fermions



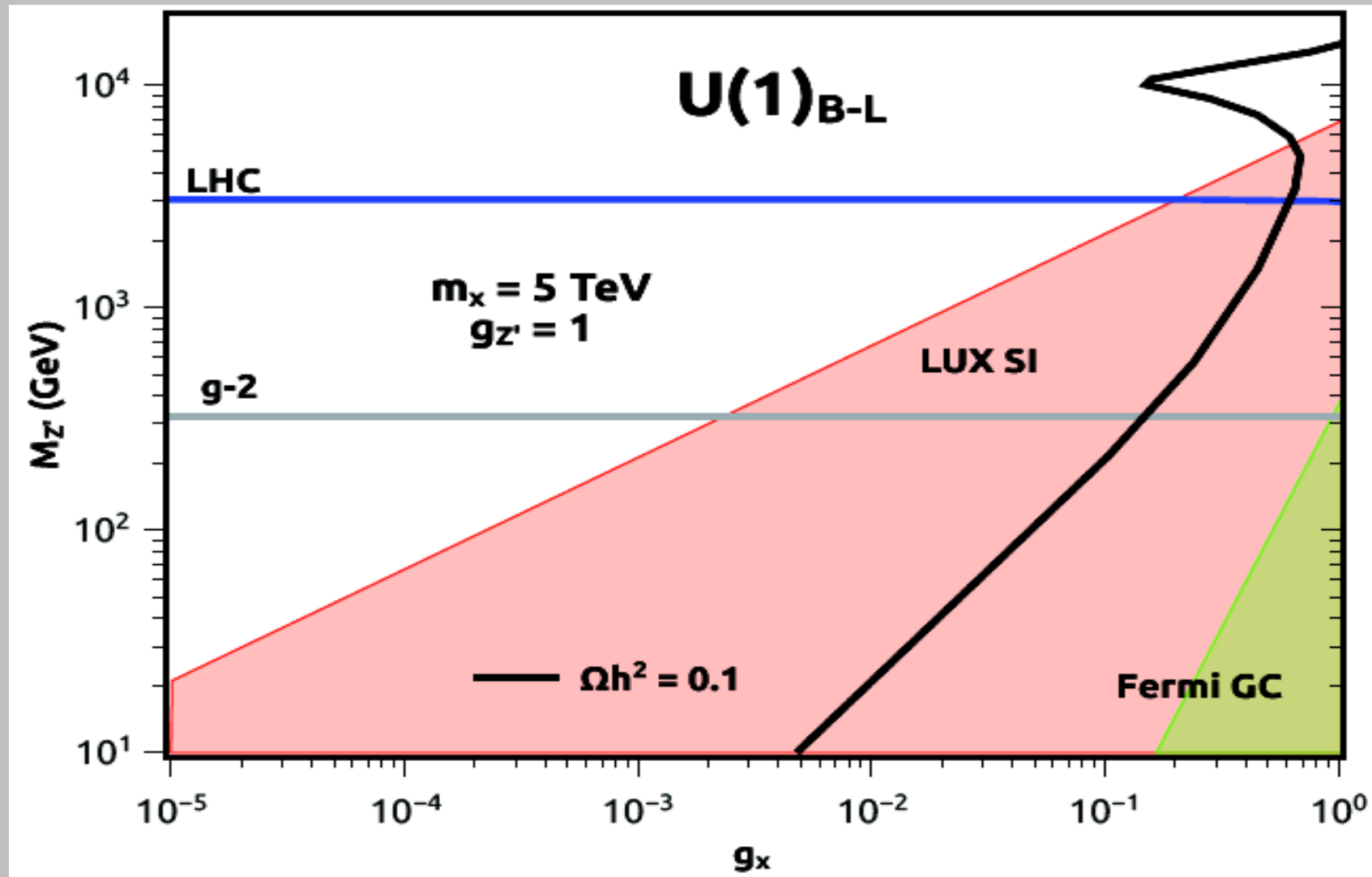
The Z'-fermion couplings are generation independent

Bounds on U(1) Gauge Models



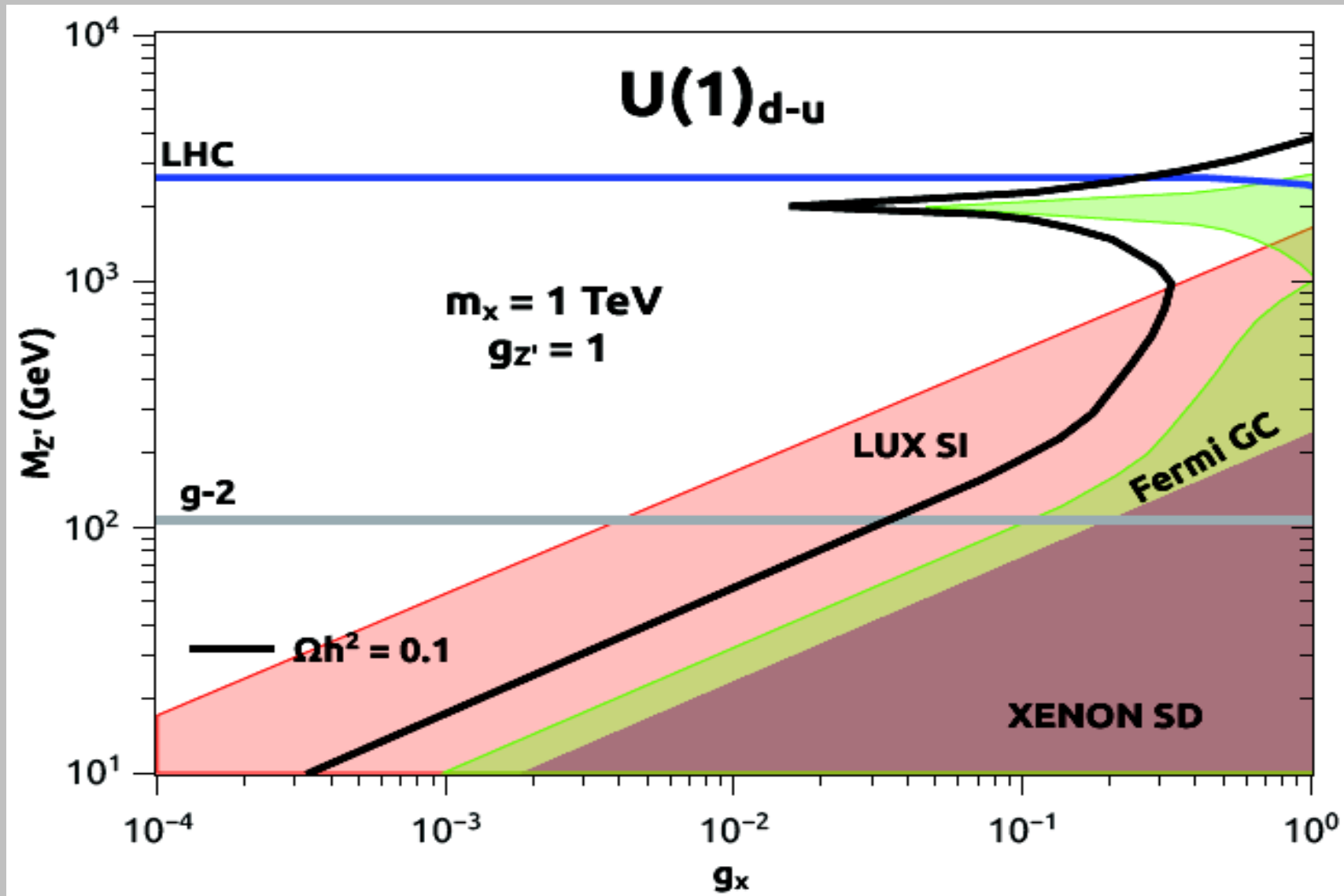
We exclude Dark Matter Masses below 1 TeV

Bounds on U(1) Gauge Models



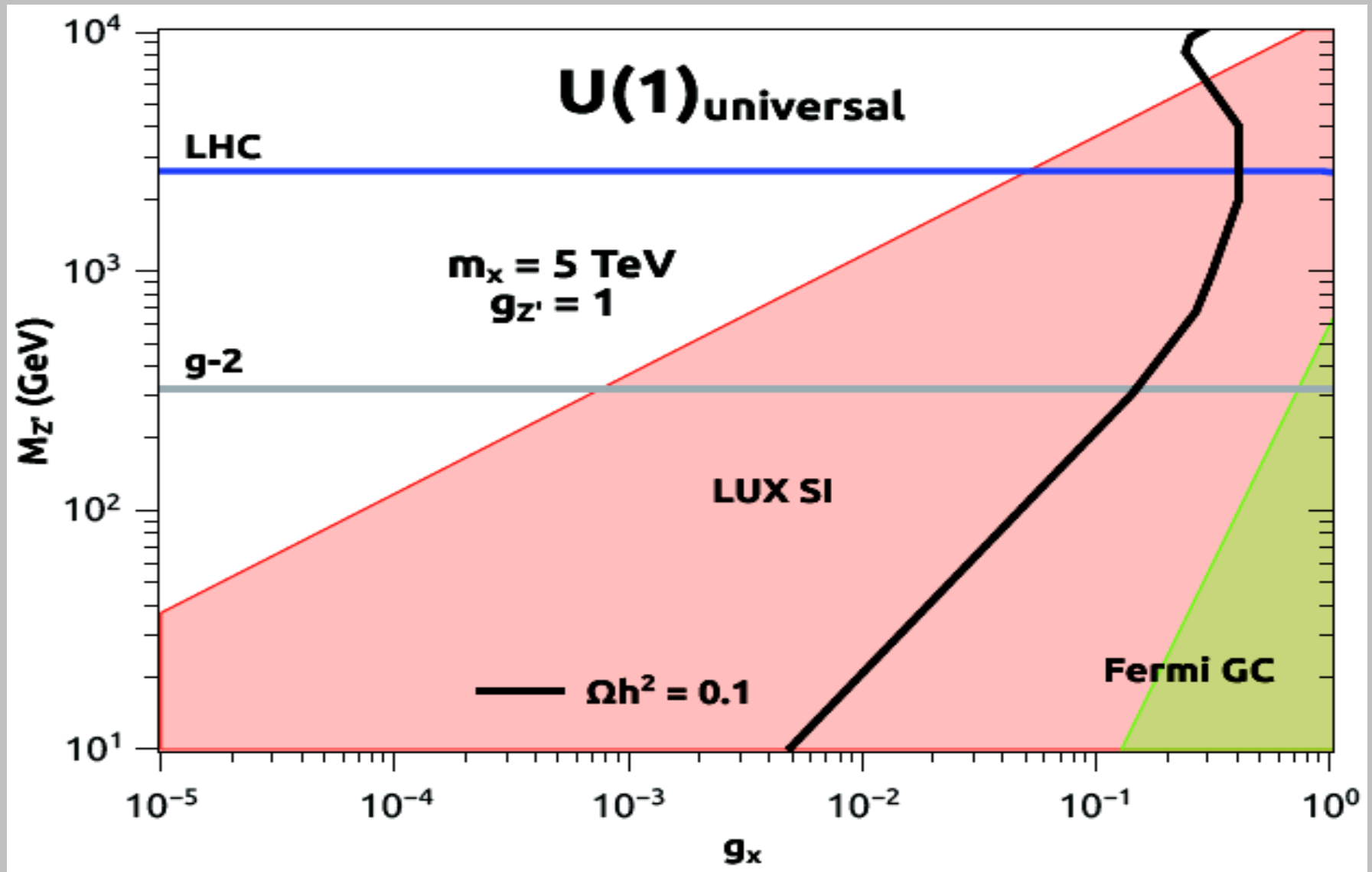
We exclude Dark Matter Masses below 2 TeV

Bounds on U(1) Gauge Models



We exclude Dark Matter Masses below $\sim 1 \text{ TeV}$

Bounds on U(1) Gauge Models



We exclude Dark Matter Masses below $\sim 5 \text{ TeV}$

Today: Updated Bounds on Left-Right Models

Stringent Dilepton Bounds on Left-Right Models using LHC data

Sudhanwa Patra^{1,2}, Farinaldo S. Queiroz¹, Werner Rodejohann^{1*}

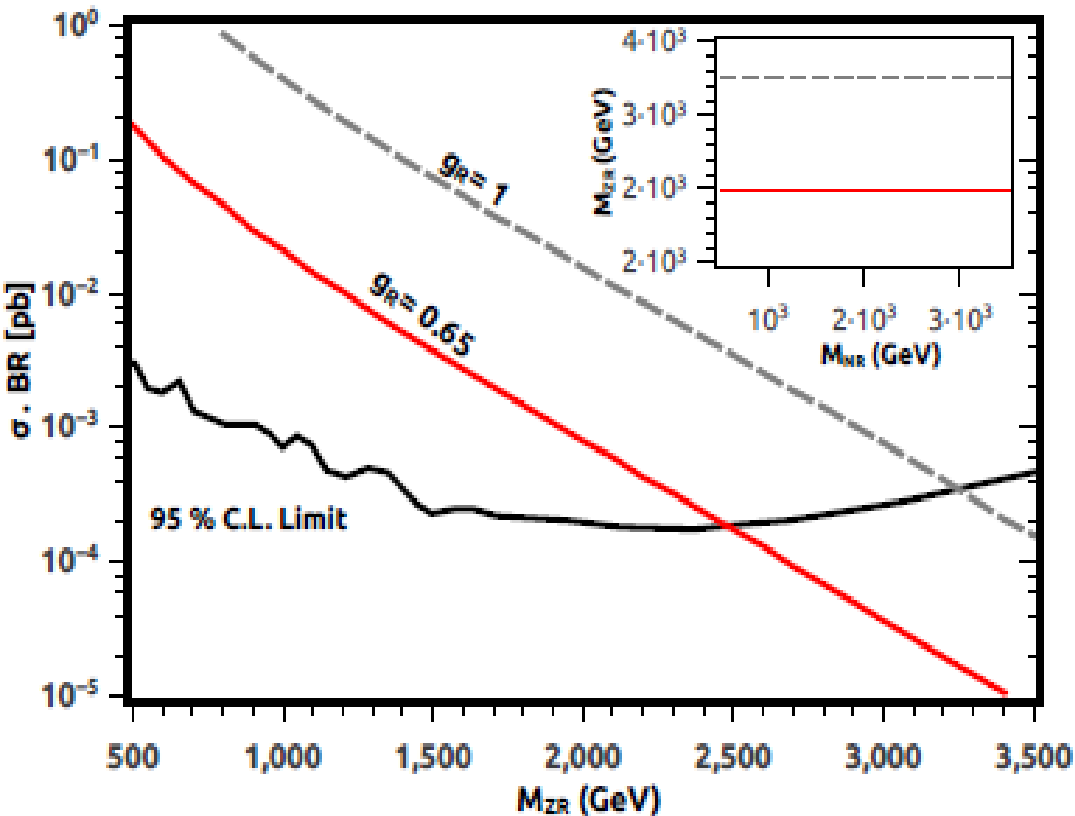
¹Max-Planck-Institut für Kernphysik,

Postfach 103980, 69029 Heidelberg, Germany

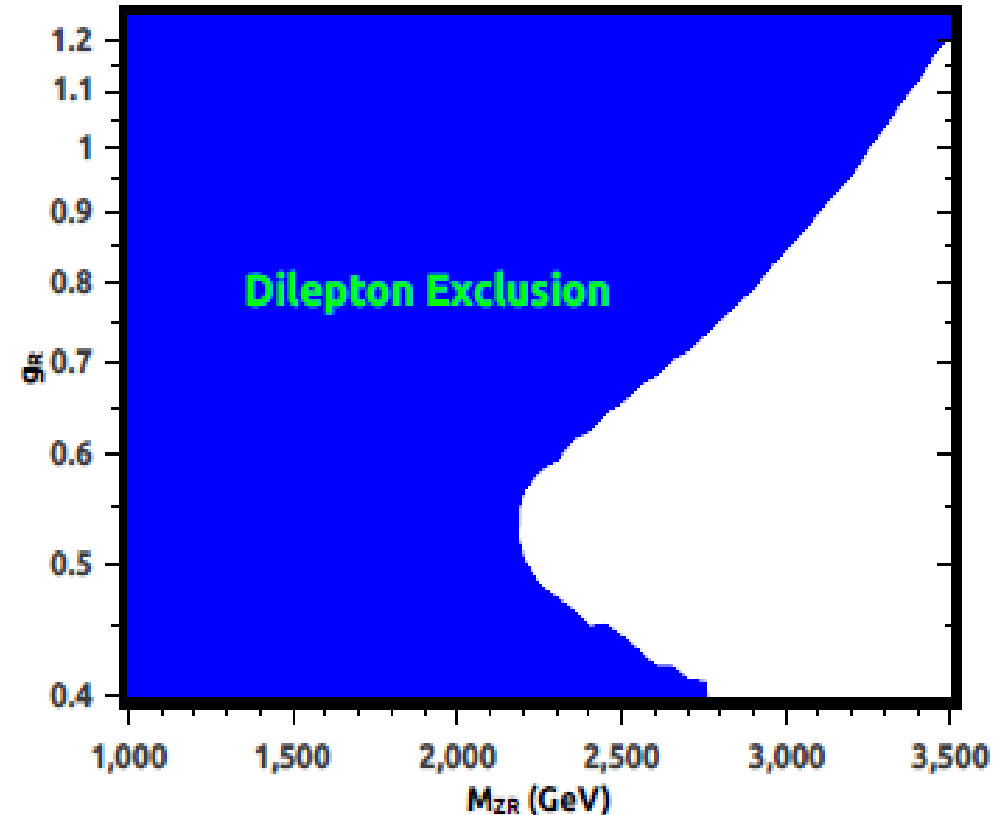
² Center of Excellence in Theoretical and Mathematical Sciences,
Siksha 'O' Anusandhan University, Bhubaneswar-751030, India

In canonical left-right symmetric models the lower mass bounds on the charged gauge bosons are in the ballpark of 3 – 4 TeV, resulting into much stronger limits on the neutral gauge boson Z_R , making its production unreachable at the LHC. However, if one evokes different patterns of left-right symmetry breaking the Z_R might be lighter than the W_R^\pm motivating an independent Z_R collider study. In this work, we use the 8 TeV ATLAS 20.3 fb⁻¹ luminosity data to derive robust bounds on the Z_R mass using dilepton data. We find strong lower bounds on the Z_R mass for different right-handed gauge couplings, excluding Z_R masses up to ~ 3.2 TeV. For the canonical LR model we place a lower mass bound of ~ 2.5 TeV. Our findings are almost independent of the right-handed neutrino masses ($\sim 2\%$ effect) and applicable to general left-right models.

Patra, Rodejohann, Queiroz 2015



Patra, Rodejohann, Queiroz 2015



Just one Goal !

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Muon Anomalous Magnetic Moment

Direct and Indirect Dark Matter Detection

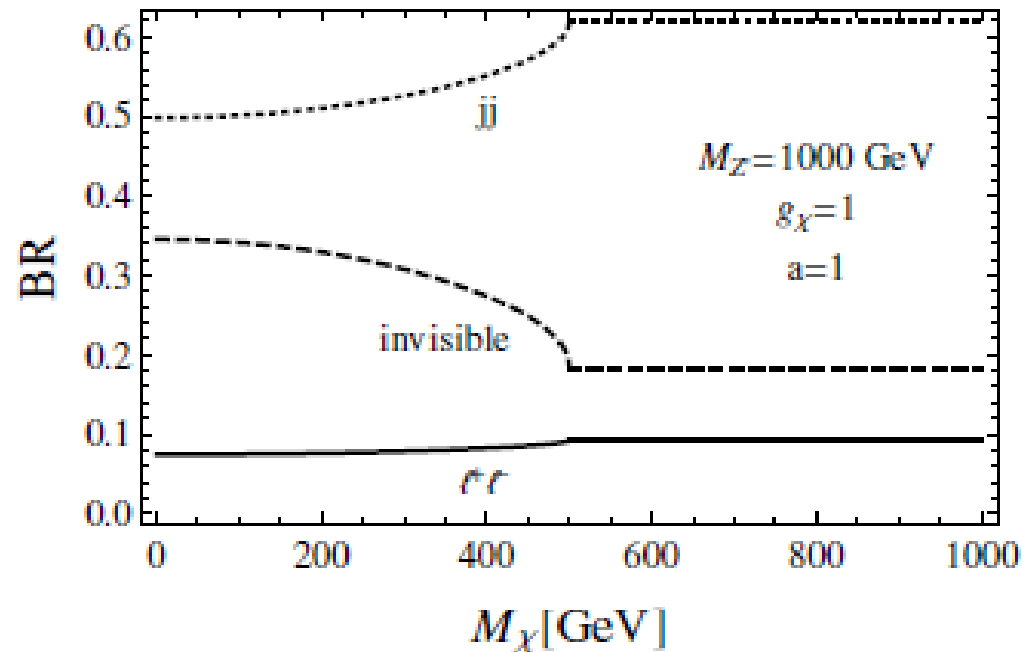
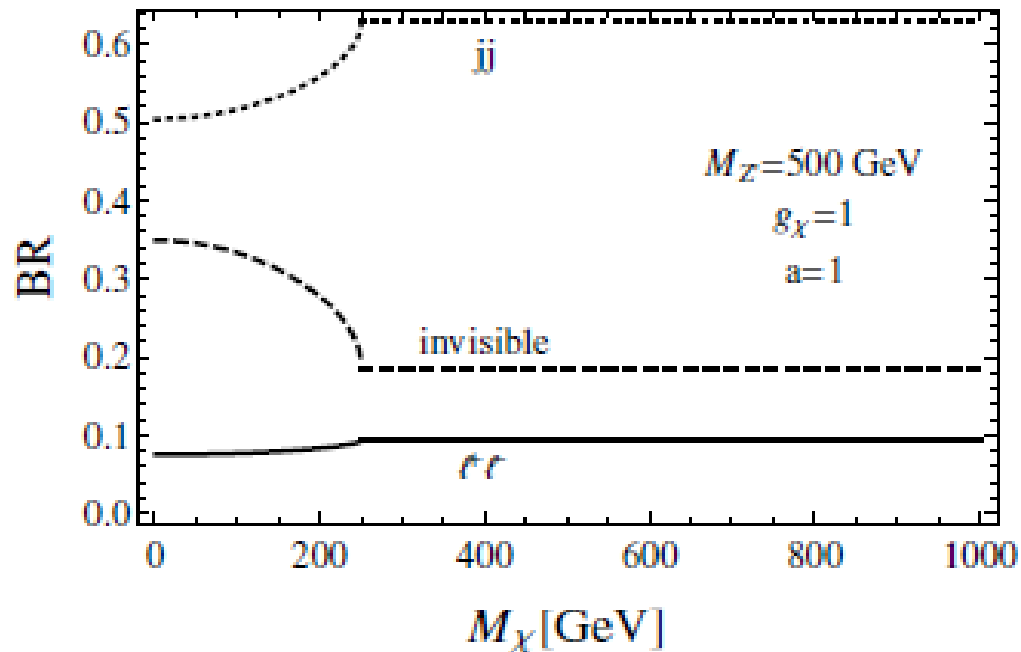
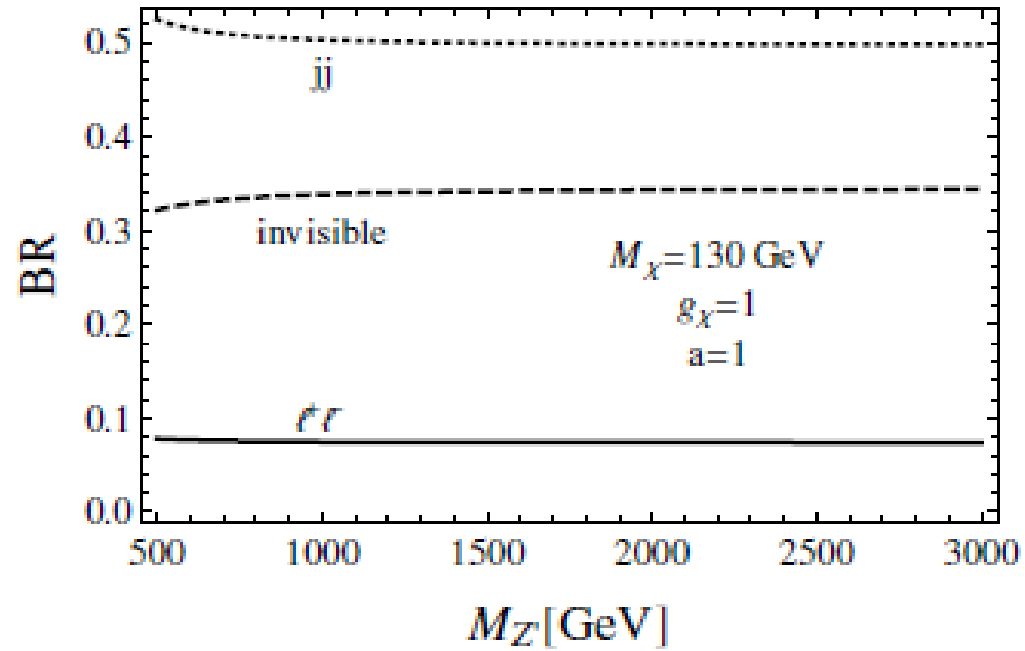
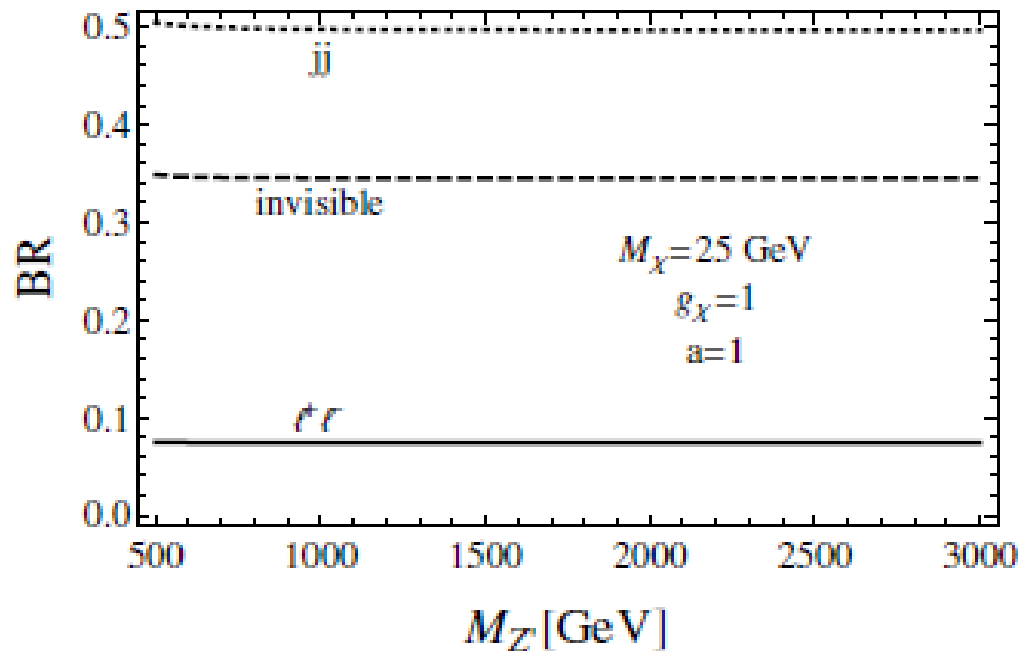
Thank you

Backup Slides

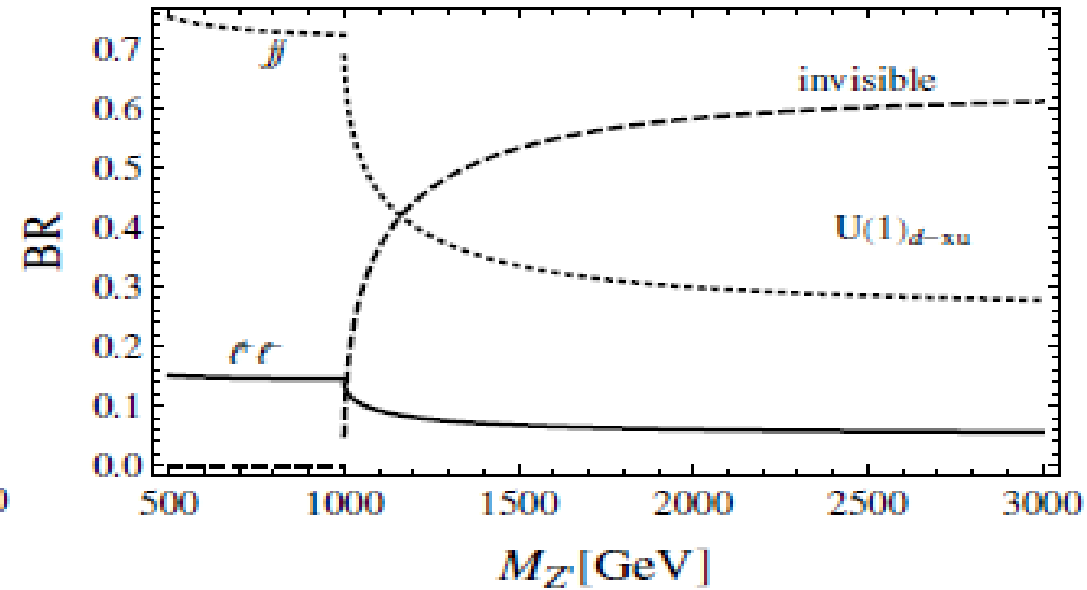
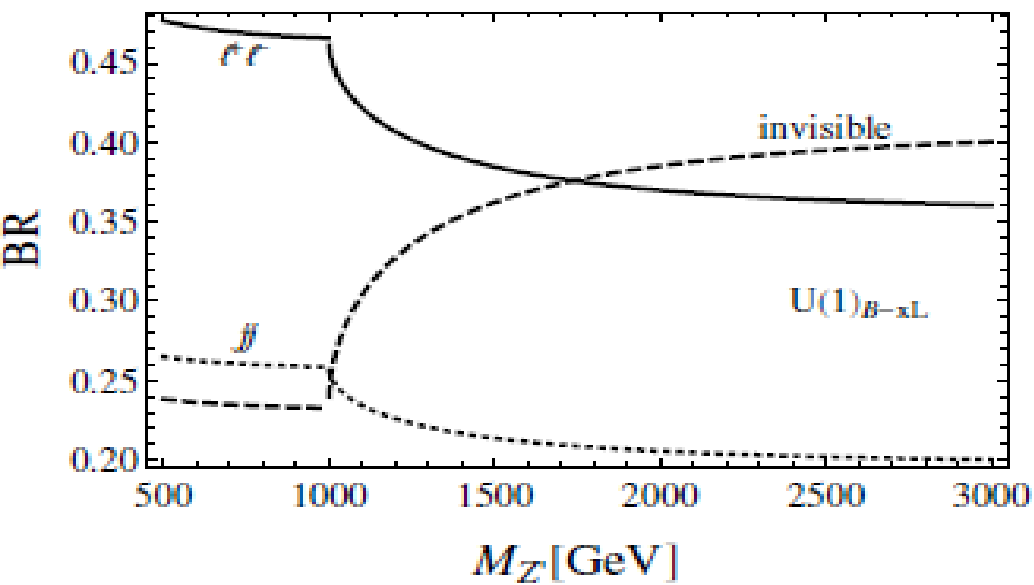
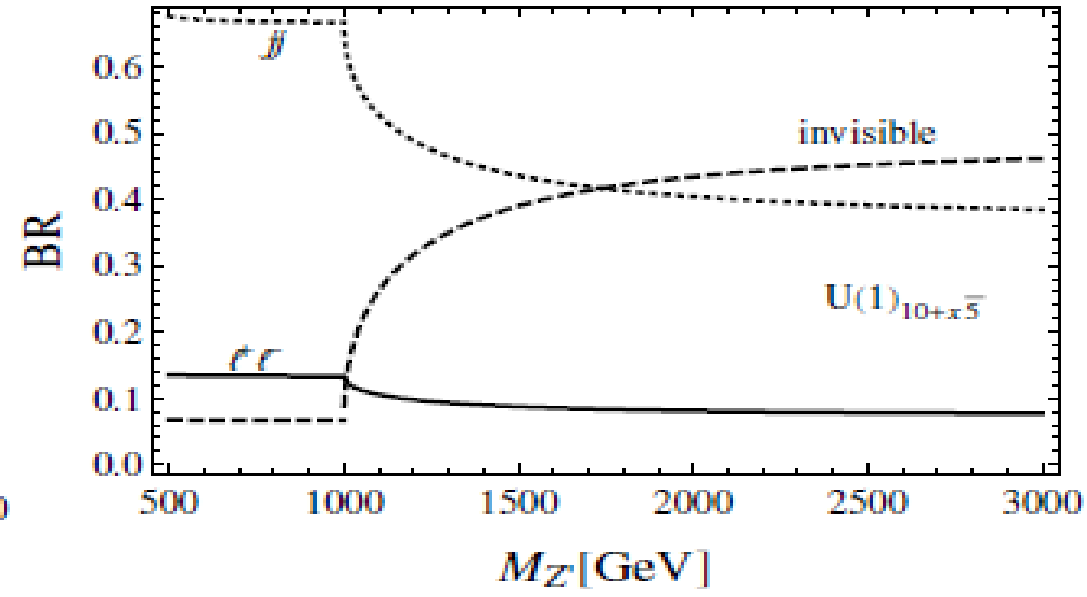
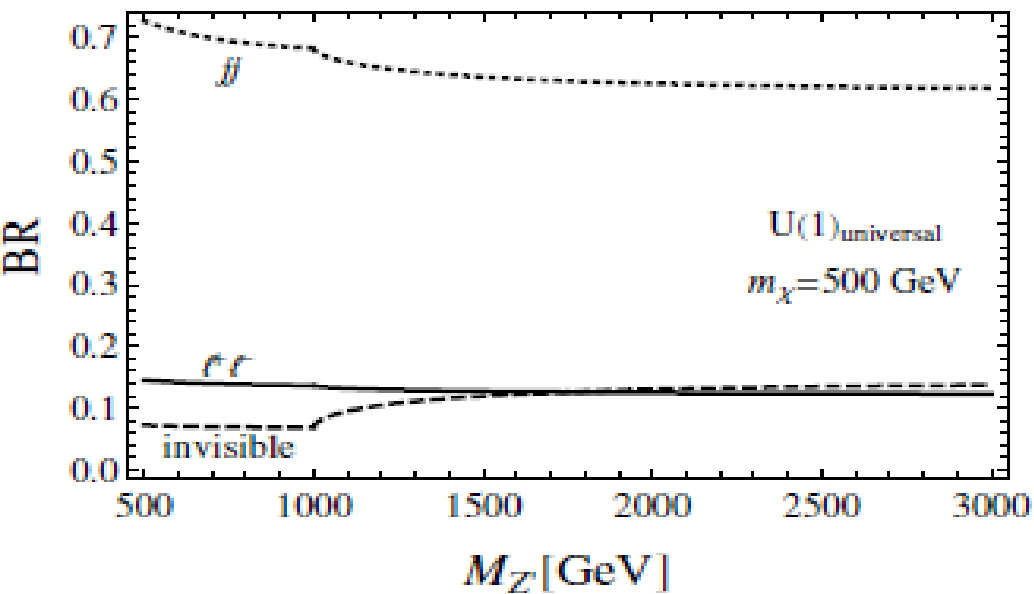
Gauge Coupling assignments

Field	$U(1)_{\text{universal}}$	$U(1)_{B-xL}$	$U(1)_{10+x\bar{5}}$	$U(1)_{d-xu}$
Q_L	x	$\frac{1}{3}$	$\frac{1}{3}$	0
u_R	x	$\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{x}{3}$
d_R	x	$\frac{1}{3}$	$-\frac{x}{3}$	$\frac{1}{3}$
l_L	x	x	$\frac{x}{3}$	$\frac{-1+x}{3}$
e_R	x	x	$-\frac{1}{3}$	$\frac{x}{3}$

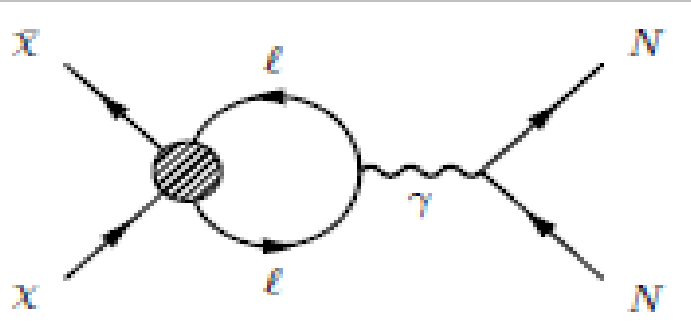
Branching Ratios in the simplified Z' Model with couplings to all fermions



Branching Ratios for four different U(1) gauge structures

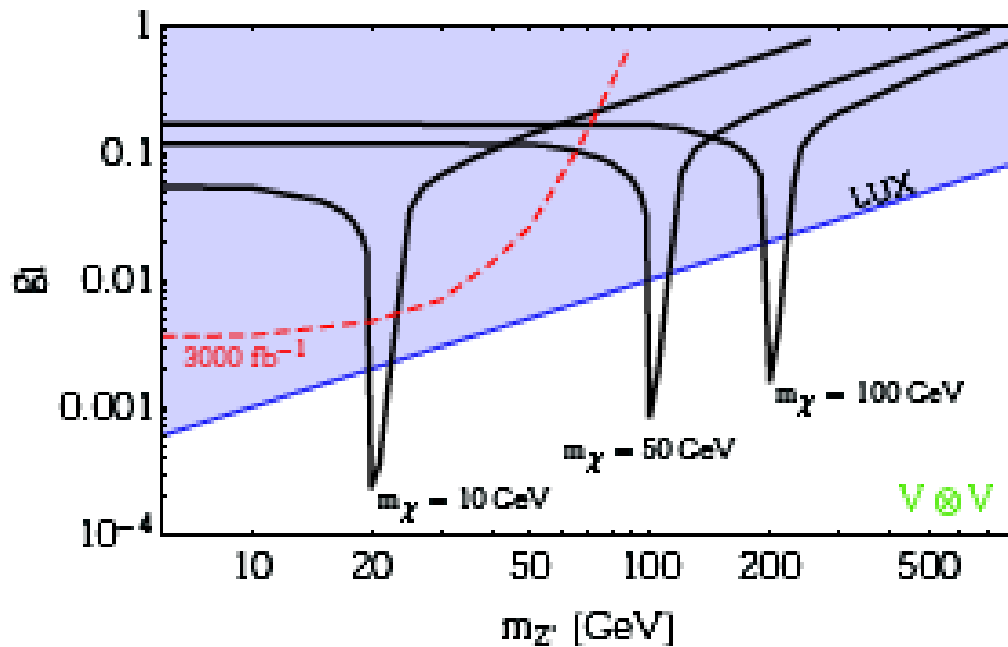


Leptophilic Z'

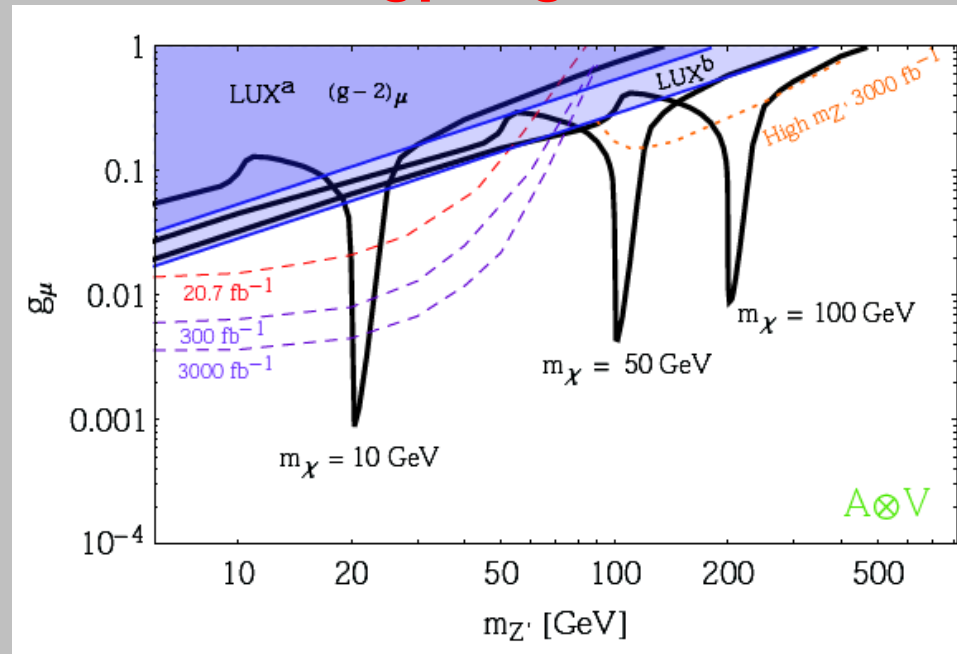


1407.3001

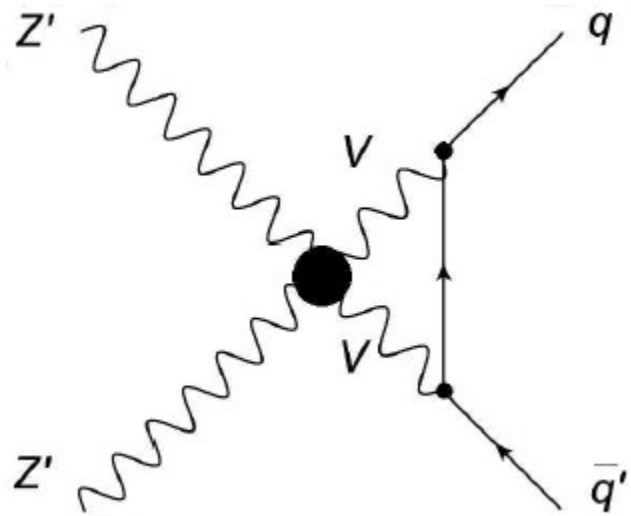
$$g_l = g_X$$



$$g_\mu = g_X$$



Fermiophobic Z'



1403.2918

