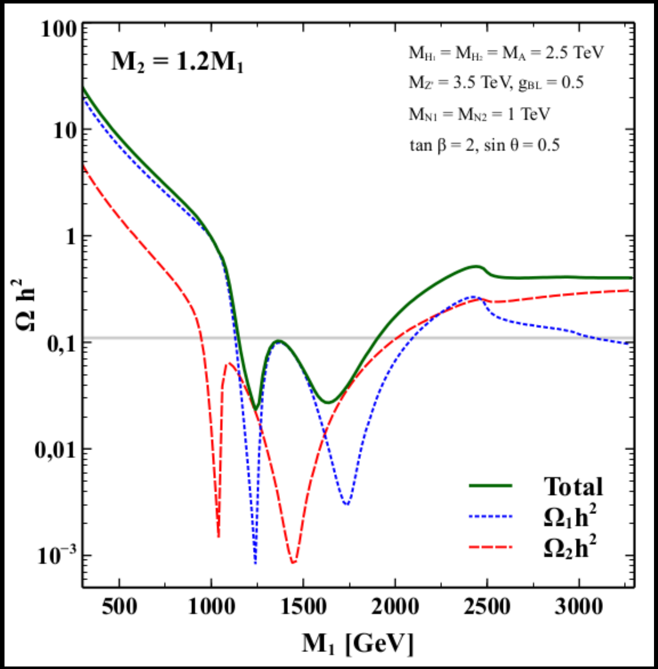
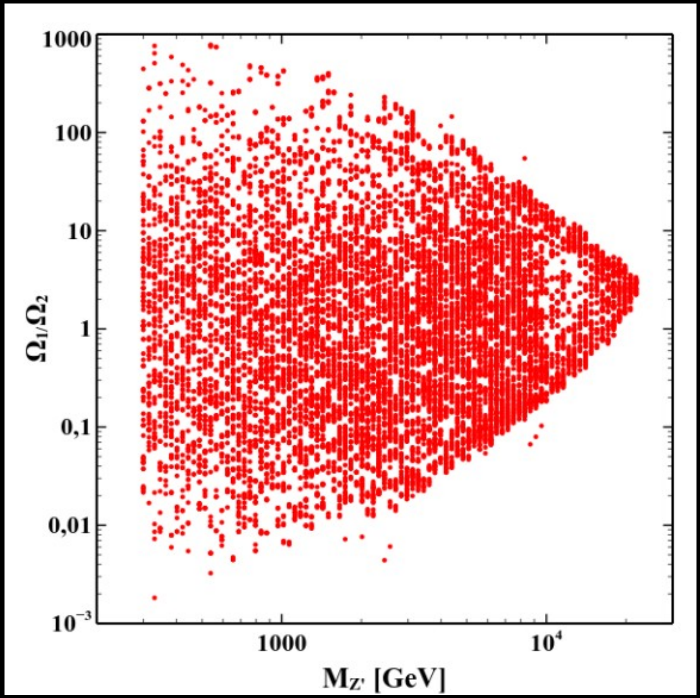
Two-component dark matter in a new B-L model



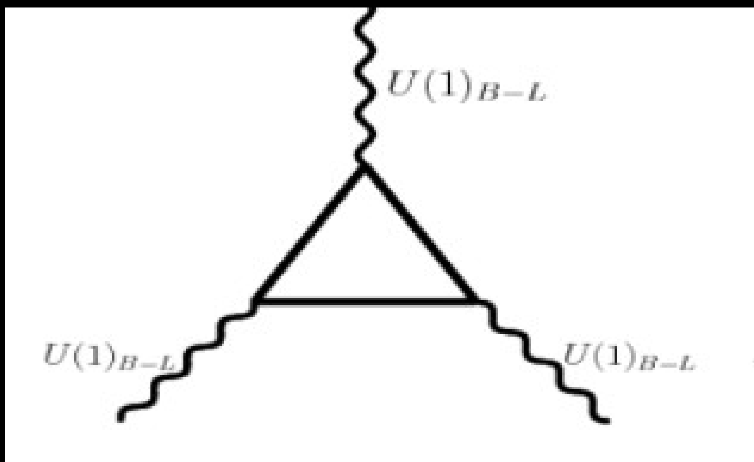


Based on 1808.03352 (PRD)
by Bernal, Restrepo, Yaguna
and Zapata

Carlos E. Yaguna
UPTC, Tunja, Colombia
2019

I will discuss a new extension of the Standard Model by a $U(1)_{B-L}$ symmetry

1. Motivation



2. The model

ξ_L	$10/7$	$(1,1,0)$
η_R	$-4/7$	$(1,1,0)$
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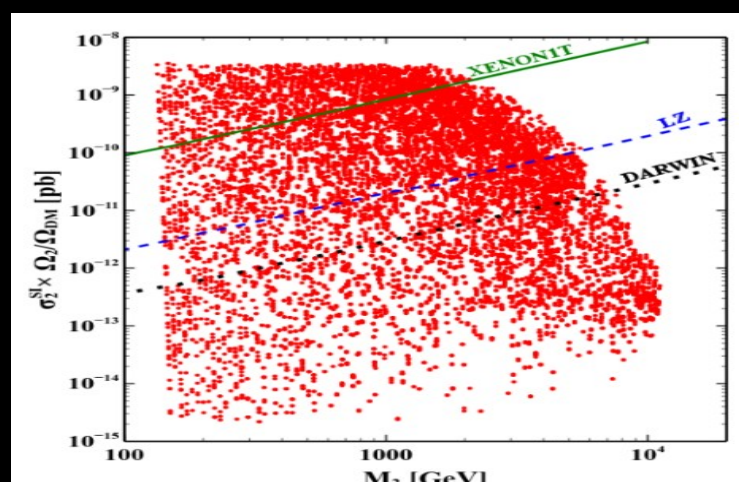
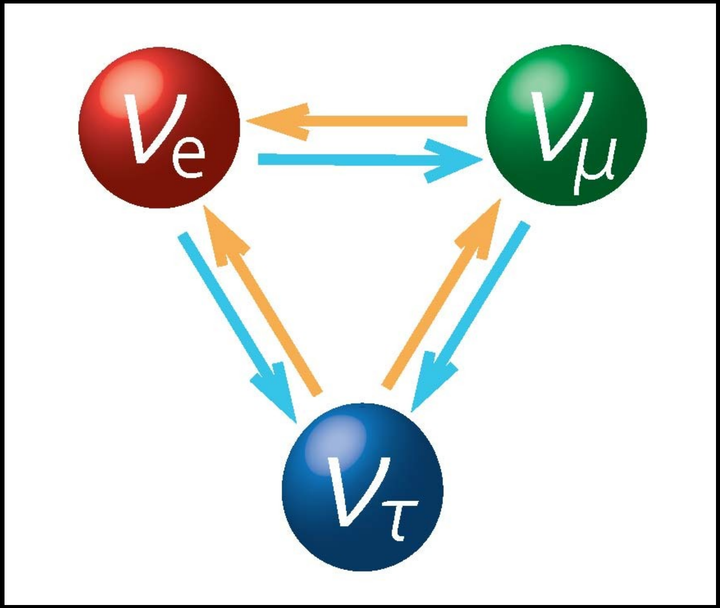
χ_L	$-9/7$	$(1,1,0)$

3. DM Predictions

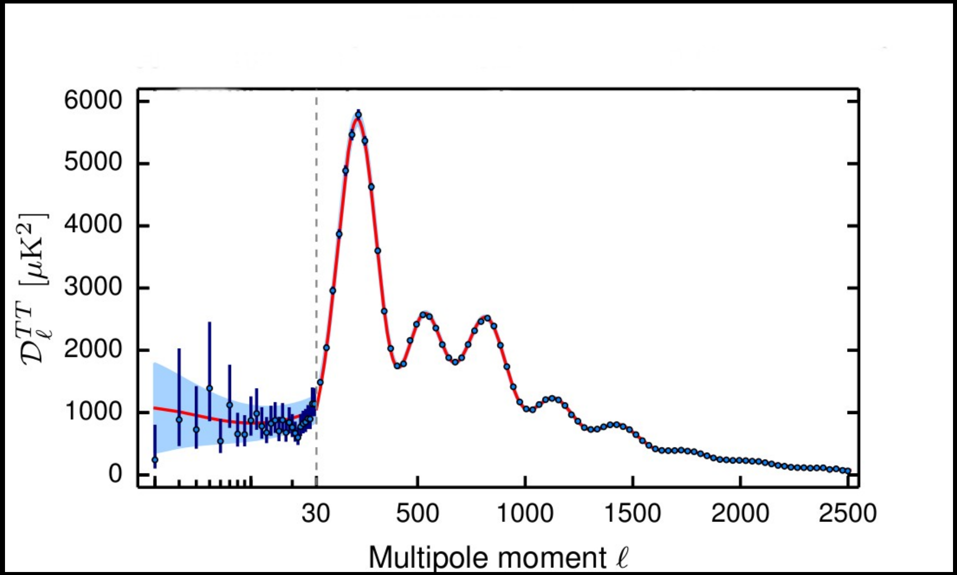


Currently there is solid evidence of physics beyond the Standard Model

Neutrino oscillations have been observed



Dark matter has been detected



What we do not know yet is what this new physics looks like

SUSY does not seem to be the answer

No signals at the LHC

Different models for neutrino masses

Seesaws, loops, symmetries, ...

Several possible DM candidates

Wimps, axions, scalars, ν_s,...

Baryon number (B) and Lepton number (L) are accidental symmetries of the SM

They are conserved automatically

No proton decay

Can they be gauged?

They are both anomalous

B-L is almost free of anomalies

Easier to gauge!

Models extended with a $U(1)_{B-L}$ are a compelling alternative for new physics

They allow to explain neutrino masses

e.g. via the seesaw

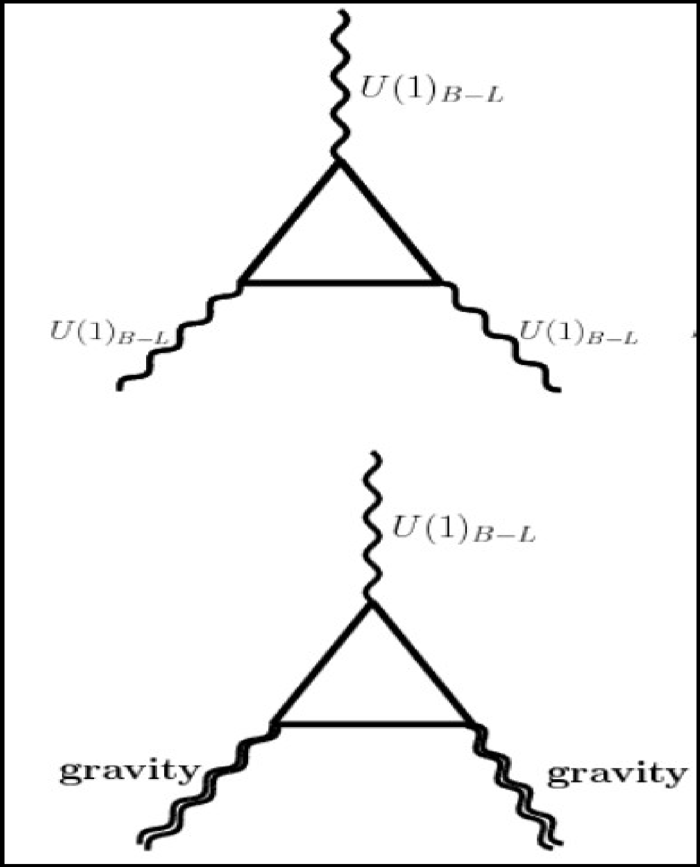
DM candidates can be incorporated

Fermion or Scalar

They include a new gauge boson (Z')

Signals at the LHC
LEP: $M_{Z'}/g_{BL} > 7$ TeV

These models require new fermions to cancel the gauge anomalies



They must be SM singlets

But their number is not fixed

Infinite solutions are possible

$$\sum Y_{B-L} = -3, \sum Y^3_{B-L} = -3$$

The simplest way to cancel the B-L anomalies is to add three ν_R

Each of them has L = 1

$$\sum Y_{B-L} = -3, \sum Y_{B-L}^3 = -3$$

ν masses can be easily explained

Majorana or Dirac

What about dark matter?

Vector-like fermion or a scalar

The B-L anomaly conditions can also be satisfied in other ways

With 3 fields another solution is -4,-4,5

Several ν mass models

A 4-field solution is:
-4/3,-2/3,-2/3,-1/3

It easily leads to DM

Could DM and ν masses be related by the anomaly conditions?

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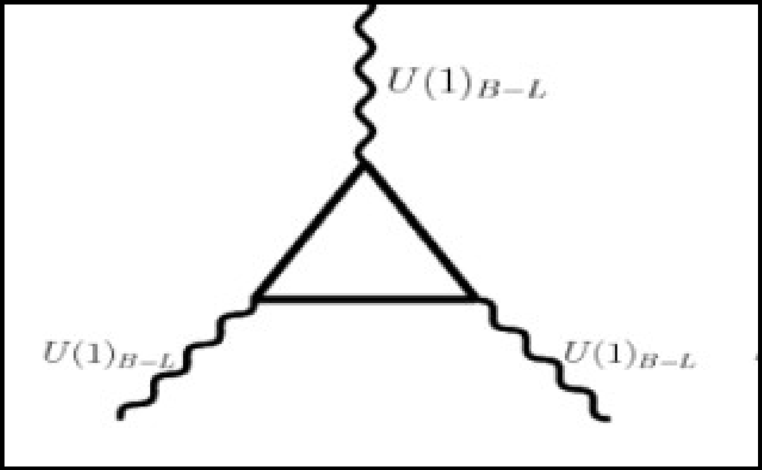

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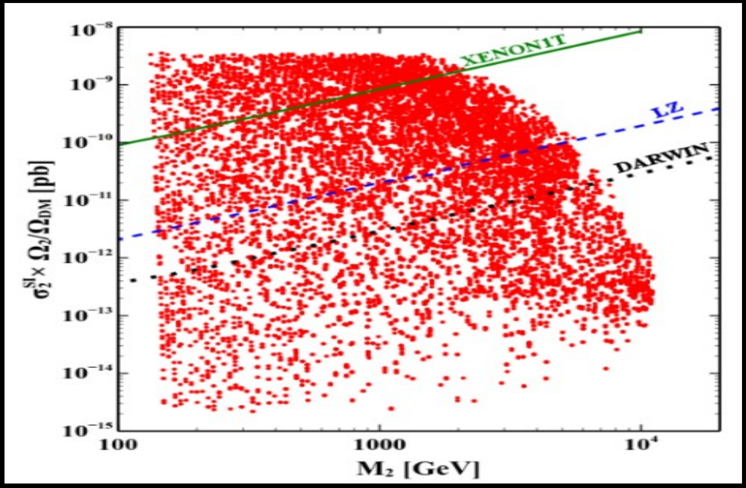
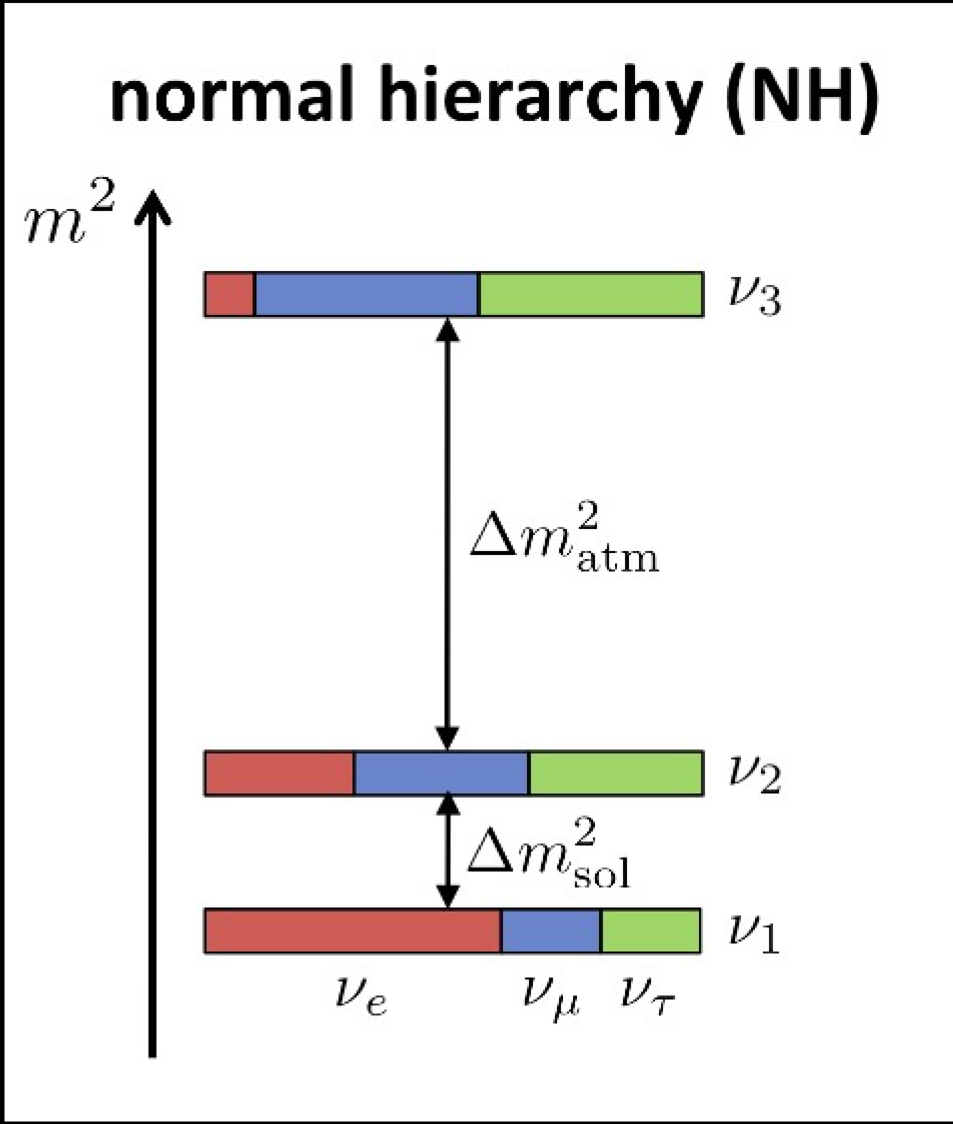


Current neutrino data is consistent with just two massive neutrinos

A seesaw with 2 RH ν's is viable

But they do not cancel the anomalies

The extra fermions explain the DM



We propose to cancel the anomalies with RH neutrinos and DM particles

Only 2 RH neutrinos are needed

And 4 fermions with fractional charges

Two new scalar fields are also needed

Particles	$U(1)_{B-L}$	$(SU(3)_c,\ SU(2)_L,\ U(1)_Y)$
Q_{Li}	$1/3$	$(\mathbf{3},\ \mathbf{2},\ 1/6)$
u_{Ri}	$1/3$	$(\bar{\mathbf{3}},\ \mathbf{1},\ 2/3)$
d_{Ri}	$1/3$	$(\bar{\mathbf{3}},\ \mathbf{1},\ -1/3)$
L_i	-1	$(\mathbf{1},\ \mathbf{2},\ -1/2)$
e_{Ri}	-1	$(\mathbf{1},\ \mathbf{1},\ -1)$
N_{R1}	-1	$(\mathbf{1},\ \mathbf{1},\ 0)$
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χ_L	$-9/7$	$(\mathbf{1},\ \mathbf{1},\ 0)$
H	0	$(\mathbf{1},\ \mathbf{2},\ 1/2)$
ϕ_1	1	$(\mathbf{1},\ \mathbf{1},\ 0)$
ϕ_2	2	$(\mathbf{1},\ \mathbf{1},\ 0)$

In this model ν's are Majorana particles and the lightest one is massless

It is a seesaw with two RH neutrinos

$$m_\nu = -\frac{v^2}{2}\, y\, M_R^{-1}\, y^T$$

And with M_R at the TeV scale

$M_R \sim M_{DM} \sim \langle \Phi_2 \rangle$

Low-scale seesaw

This is consistent with current data

And testable

This model automatically includes two dark matter particles

The 4 fermions form 2 Dirac particles

$$\mathcal{L} \supset -a\,\bar{\xi}_L\,\eta_R\,\phi_2 - b\,\bar{\zeta}_R\,\chi_L\,\phi_1$$

Both are neutral and stable

Two DM particles

A two-component DM scenario is realized

Without any discrete symmetries

The model is quite simple in terms of particles and free parameters

Sector	Particles	Free Parameters
Gauge	1 (Z’)	3 ($M_{Z'}$, g_{BL}, ε)
Neutrino	2 ($N_{R1,2}$)	11 ($M_{R1,2}$, 9 Yukawas)
Dark Matter	2 ($\Psi_{1,2}$)	2 ($M_{1,2}$)
Scalar	3 ($H_{1,2}$, A)	5 ($M_{H1,2}$, M_A, θ, $\tan\beta$)

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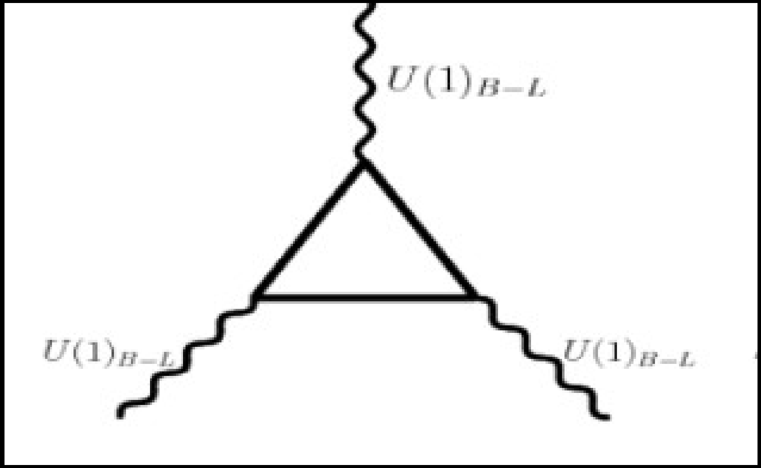

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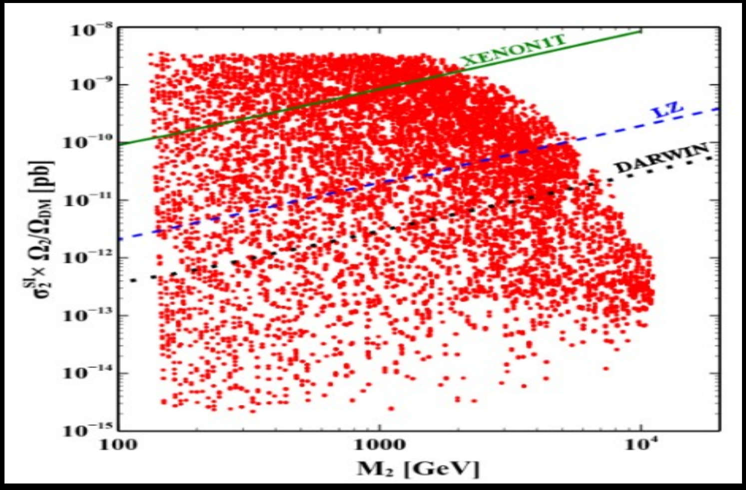
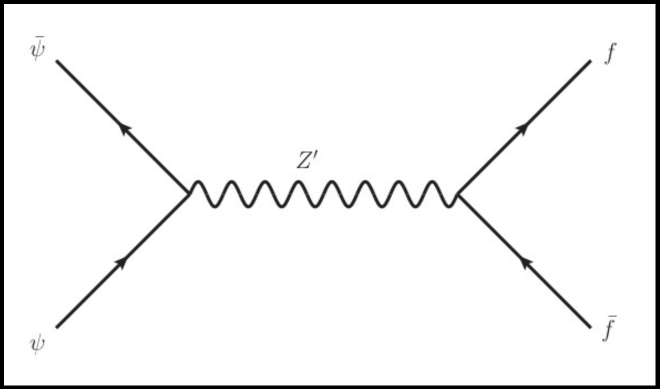
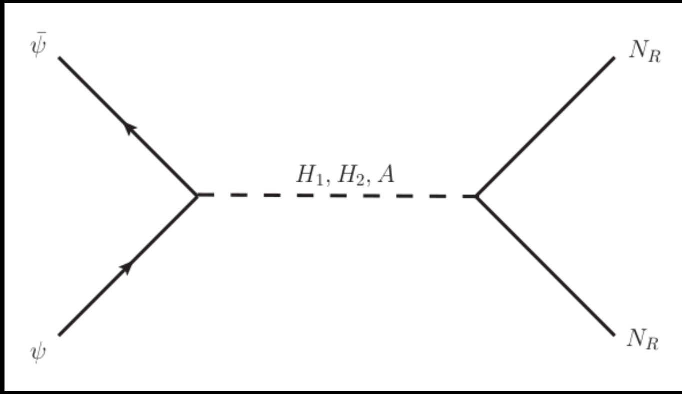


Both dark matter particles are WIMPs

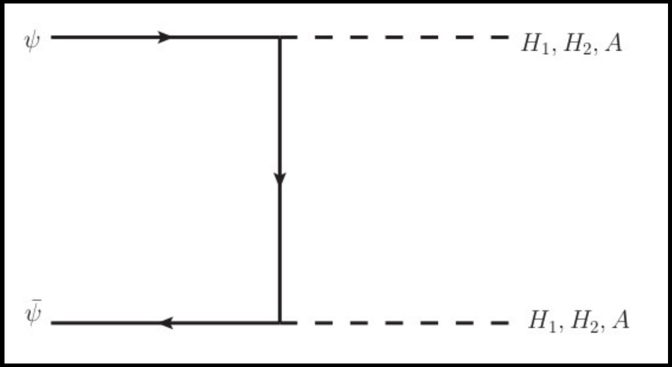
DM annihilates into different final states



They may be enhanced resonantly



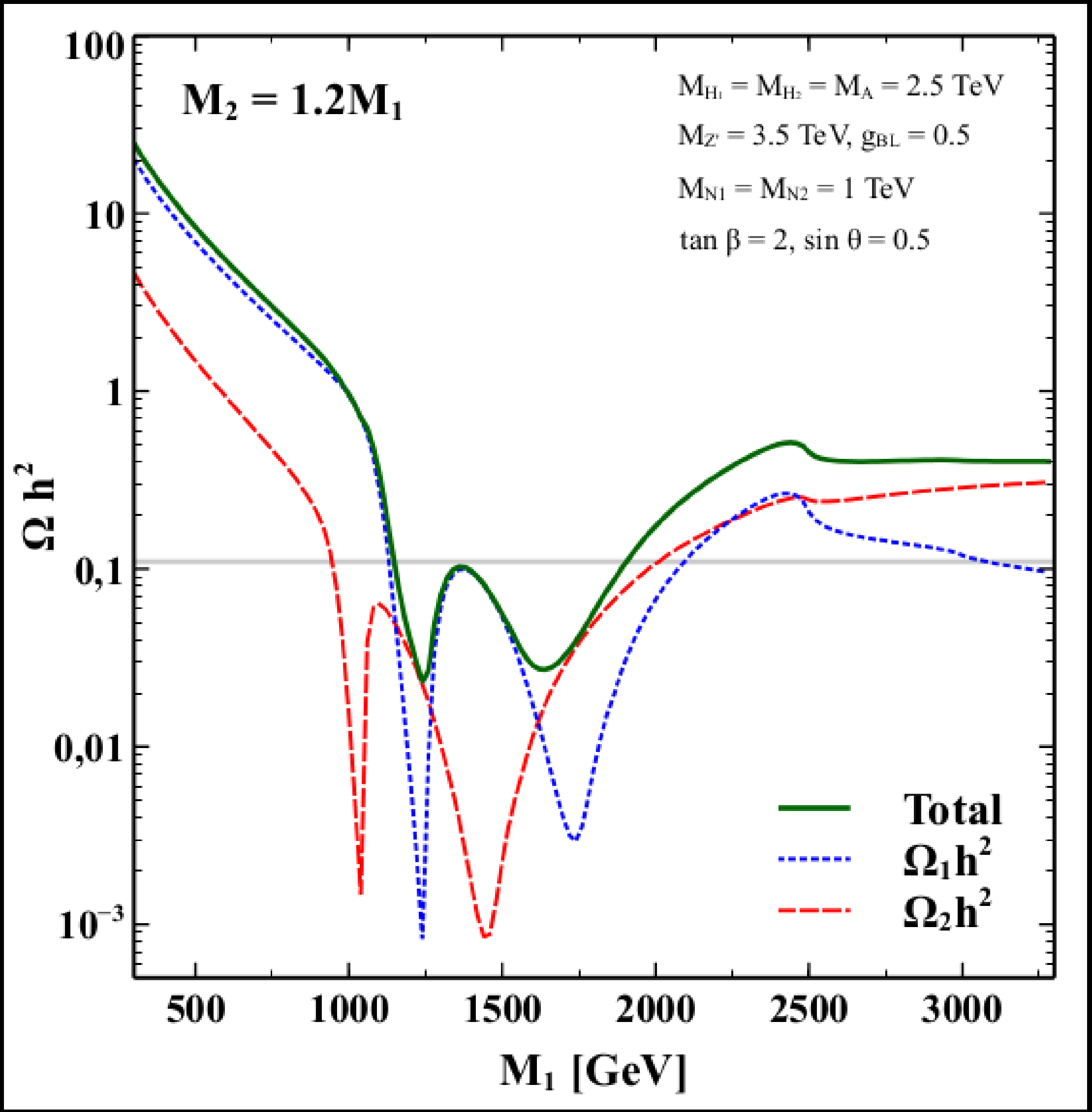
Gauge and Yukawa couplings play a role



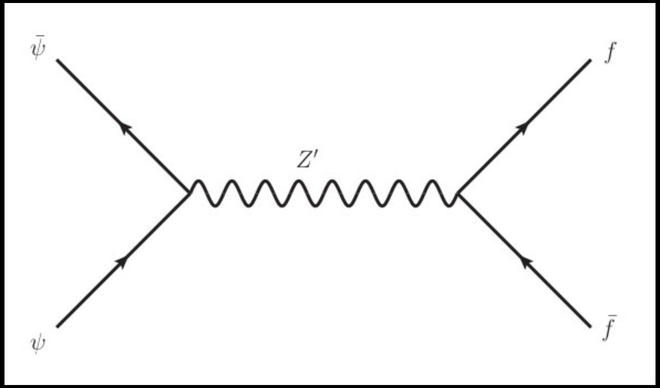
The observed dark matter density can be dominated by any of the two particles

Both DM particles contribute to Ω

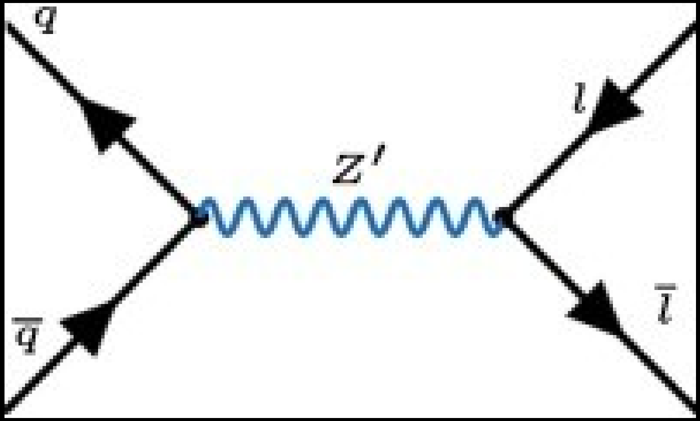
Their contributions vary significantly



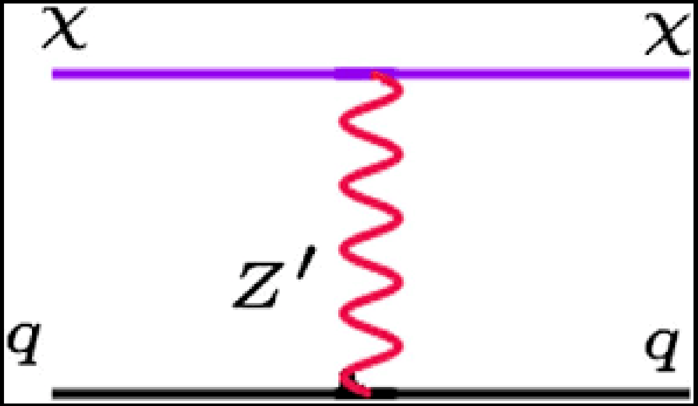
Interesting correlations are expected for DM annihilations mediated by the Z'



Ω_{DM} and indirect detection

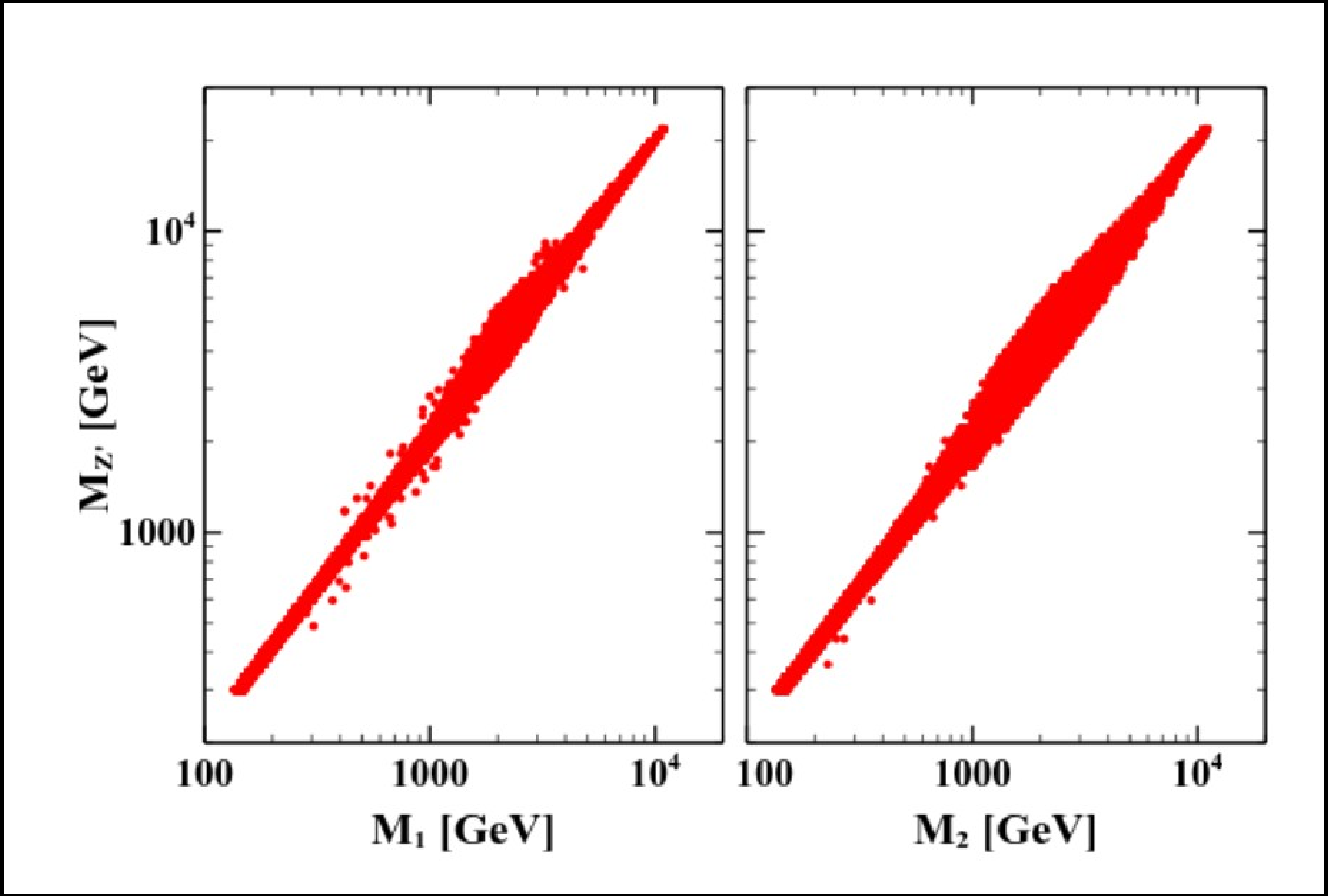


Signals at the LHC



Direct detection

Viable models feature dark matter masses as high as 11 TeV



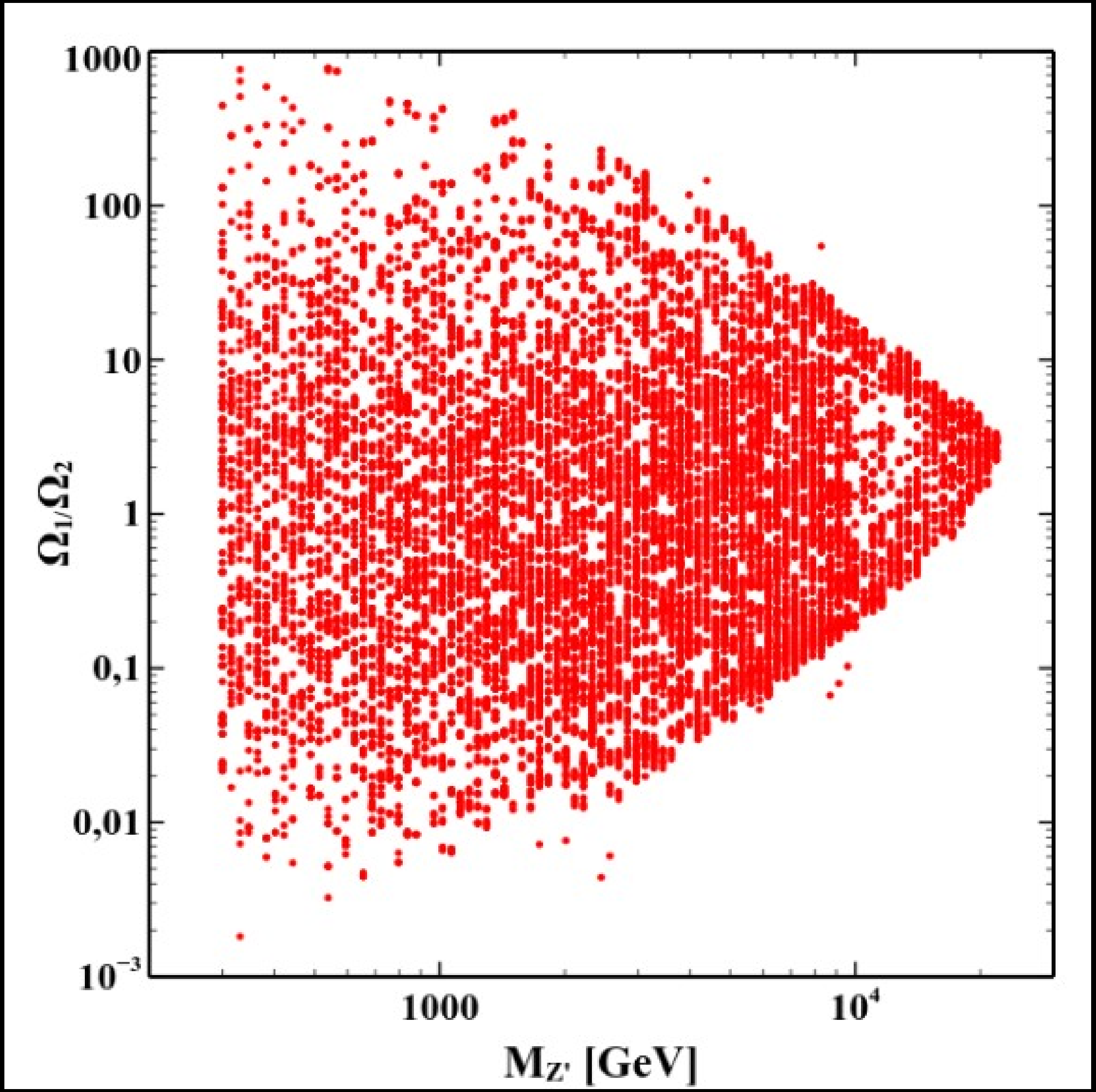
The Z' resonance is preferred

The Z' mass may reach 22 TeV

For viable models, Ω_1 and Ω_2 are of the same order at large dark matter masses

At low M_{DM}, Ω_1/Ω_2 varies over a wide range

At high M_{DM}, Ω_1/Ω_2 tends to about 3

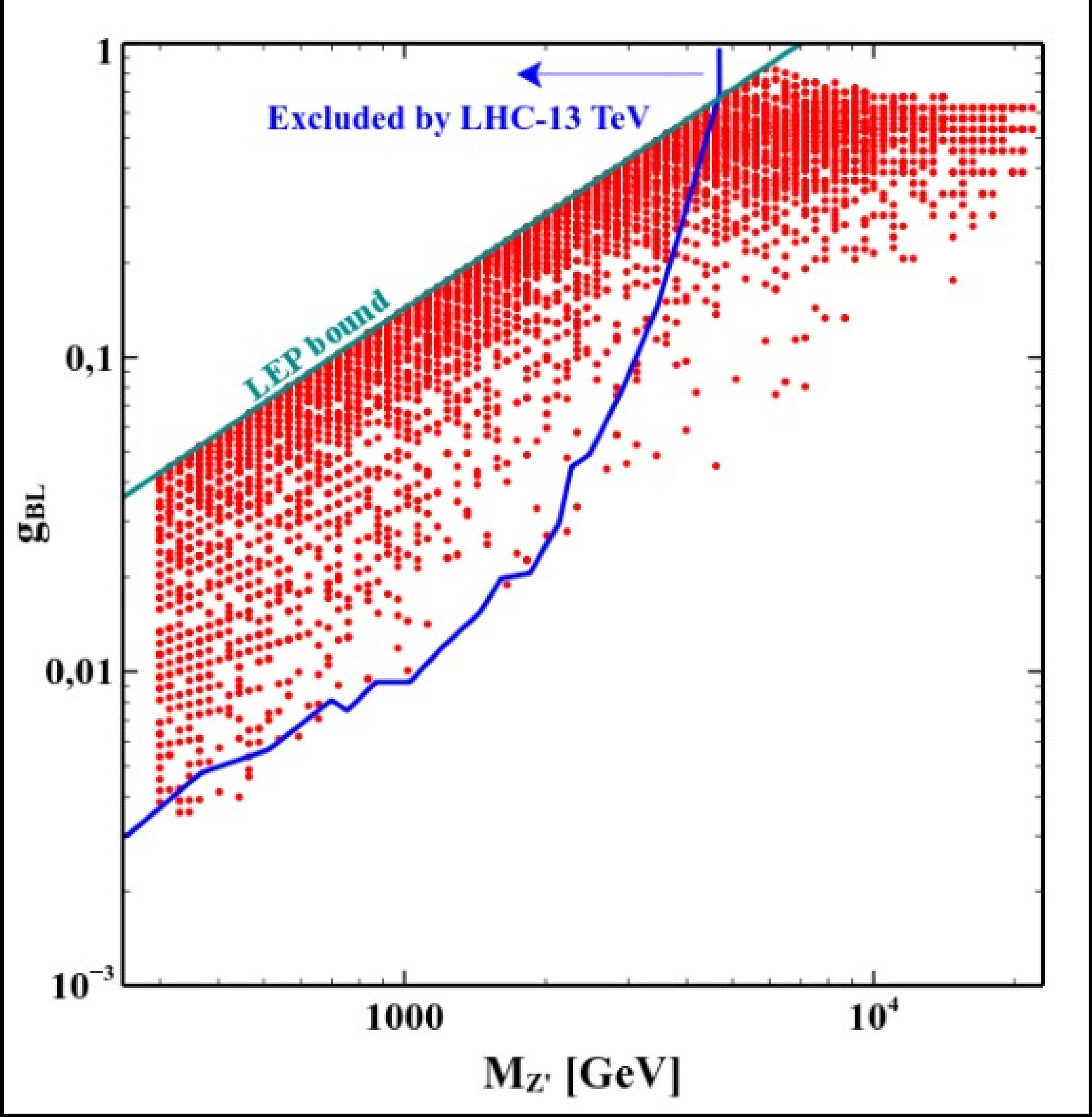


The LHC data severely restricts the low mass region of this model

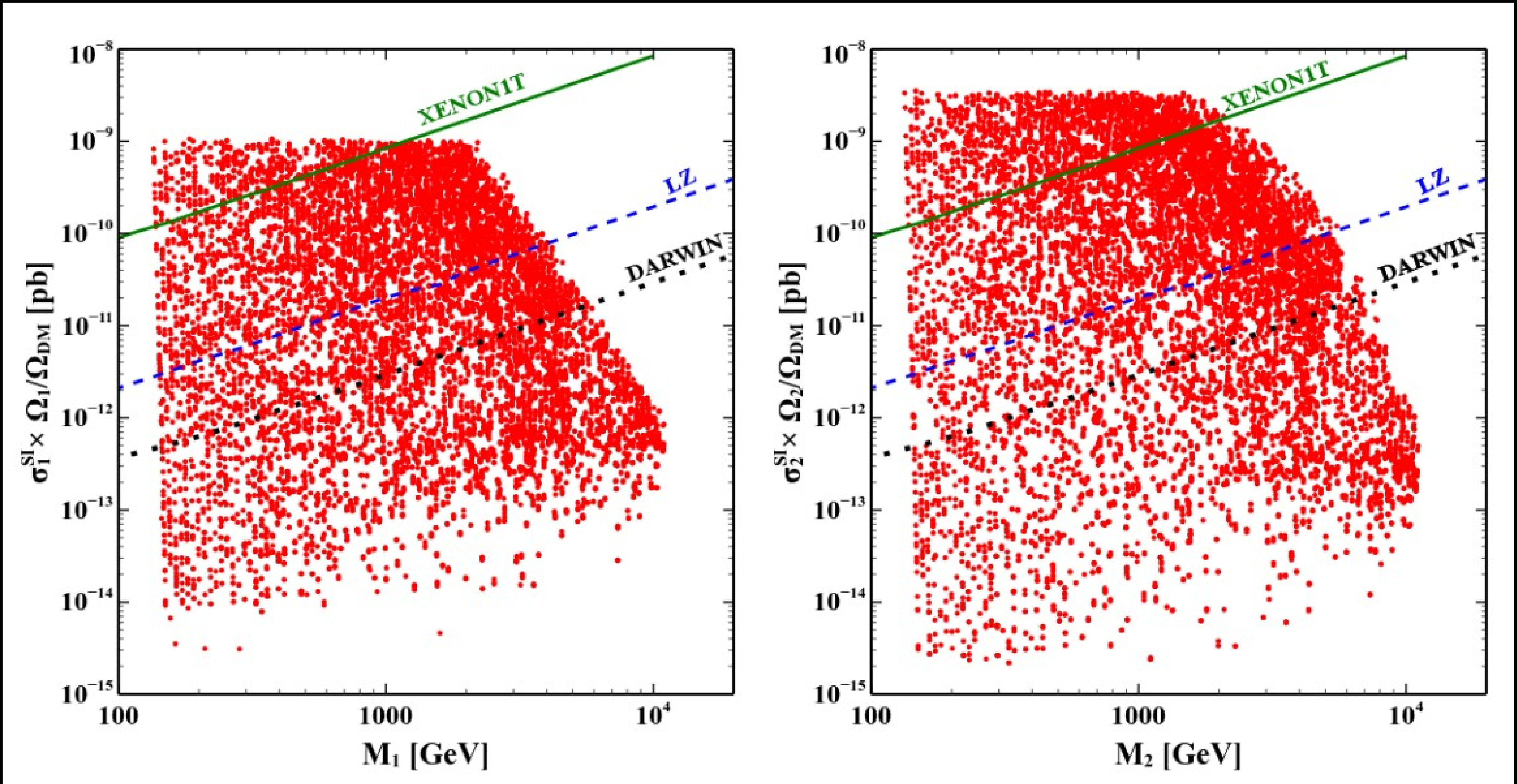
Di-lepton bounds are very constraining

Models with $M_{Z'} < 5$ TeV are nearly excluded

Viable models feature $M_{DM} > 2.5$ TeV



Future direct detection experiments will probe many viable models



We proposed an appealing extension of the SM based on the B-L gauge symmetry

It gives rise to a rich phenomenology

It contains two DM particles

It is being probed by current experiments

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