The Dark Z' Portal

Farinaldo Queiroz – University of California Santa Cruz

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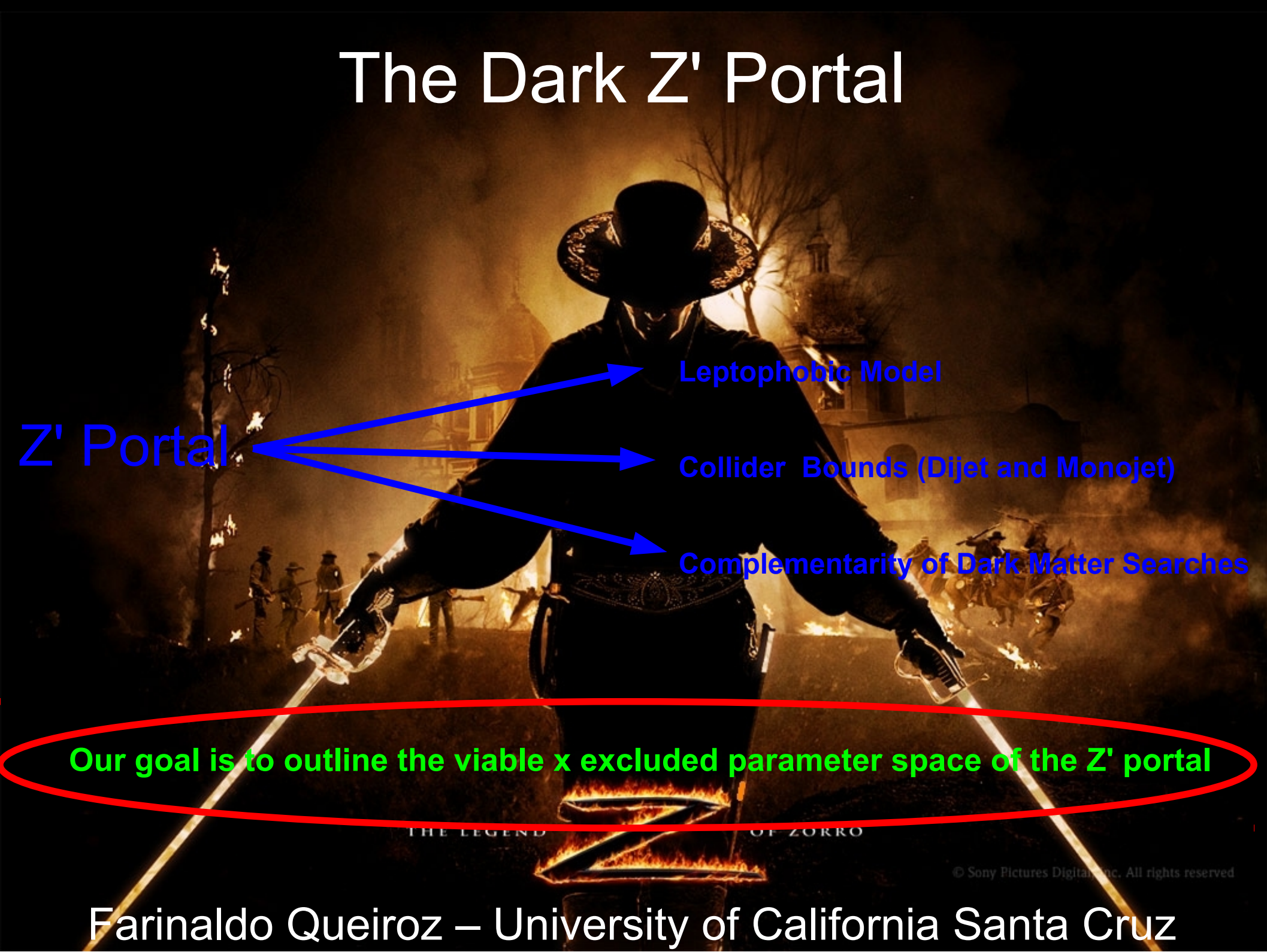

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Z' Portal

singlet fermion N + Z' boson

We are not interested in the U(1)x where the Z' comes from

This U(1)x might be anomalous and new fermions should be introduced. [Emilian Dudas at al arxiv:1307.0005]

There are different setups:
Leptophilic
Leptophobic...

Different Collider Signatures

Direct and Indirect Dark Matter Detection signals

Bounds coming from the muon anomalous magnetic moment

MUON g-2 - Numerical Code
Farinaldo Queiroz and Will Shepherd, arXiv:1403.2309

Z' Portal

$$\mathcal{L} = a\,\frac{-g}{2C_W}\left[\sum_i \bar{q}_i\gamma^\mu(\cdot g_V^i - \cdot g_A^i\gamma_5)q_i\right] Z'_\mu + g_\chi\left[\bar{\chi}\gamma^\mu(1-\gamma_5)\chi\right] Z'_\mu$$

↓

Leptophobic Z'

Only couplings to quarks have been considered

Vector/Axial couplings →

$$g_V^i = t_{3L}(i) - 2\cdot Q_i S_W^2$$
$$g_A^i = t_{3L}(i).$$

Q_i is the charge of the quark i,t_{3L} is the weak isospin of quarks, with $t_{3L} = +1/2\ (-1/2)$

Free Parameters → **a gx Mz' Mwimp**

We will investigate a=1 → Z' = Z and a=0.5 (suppressed couplings)

Z' Portal

$$\mathcal{L} = a \frac{-g}{2C_W} \left[\sum_i \bar{q}_i \gamma^\mu (g_V^i - g_A^i \gamma_5) q_i \right] Z'_\mu + g_\chi [\bar{\chi} \gamma^\mu (1 - \gamma_5) \chi] Z'_\mu$$

Leptophobic Z'

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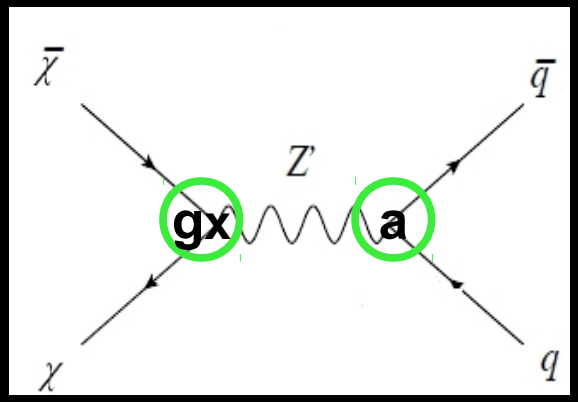
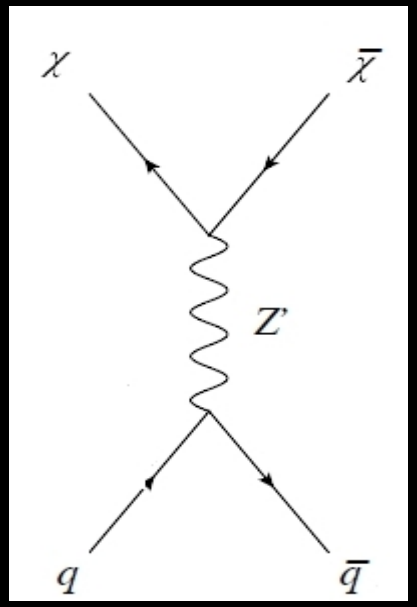
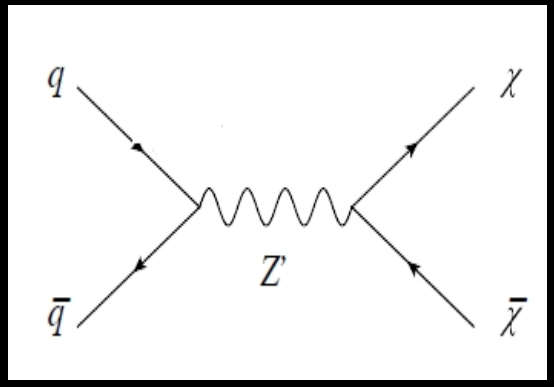
Leptophobic Z'







Indirect Detection **Direct Detection** **Collider**

Farinaldo Queiroz et al, arXiv:1312.5281

Z' Portal

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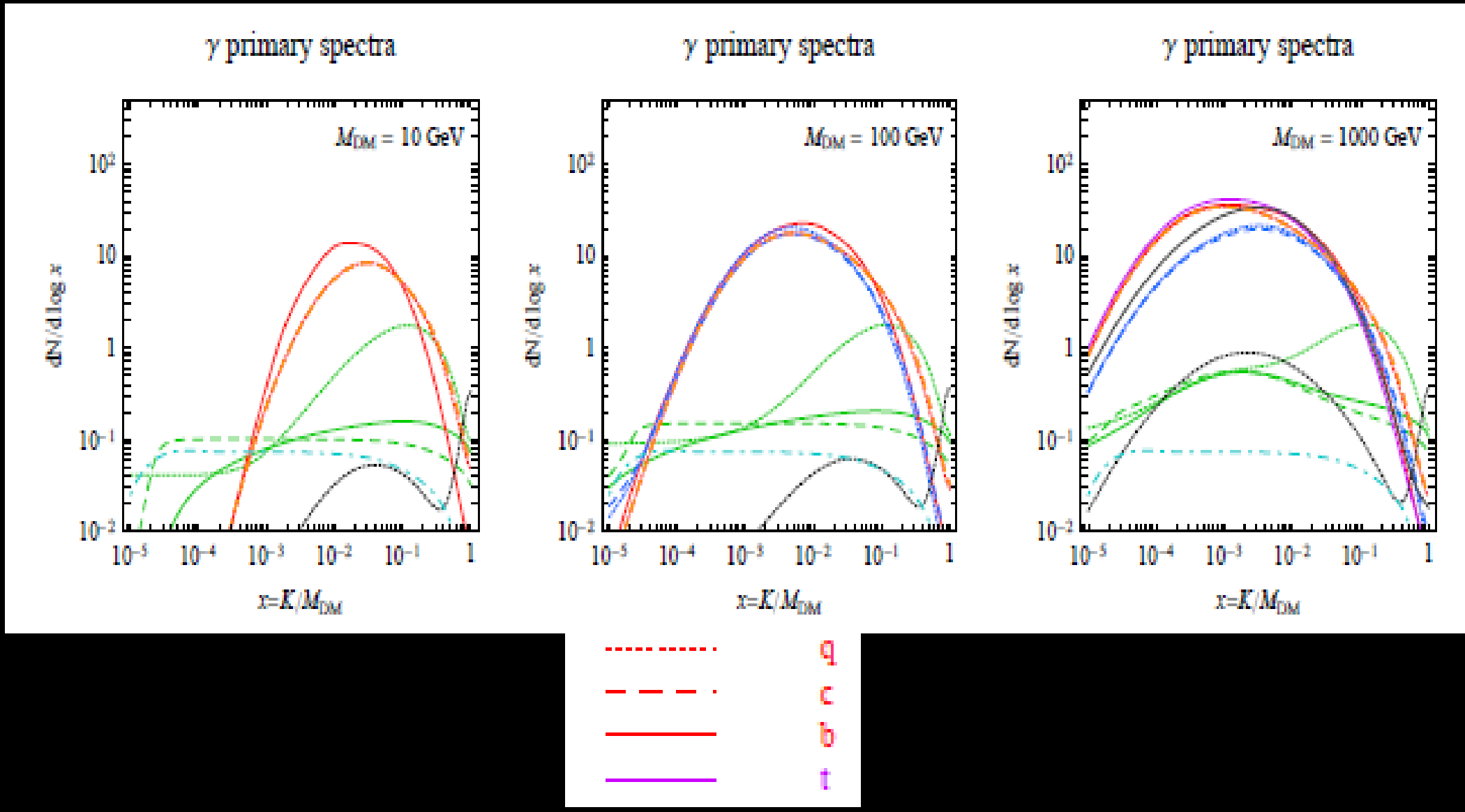
Dirac WIMP – Quarks Interactions

The Leptophobic Dark Z' Portal

	Operator	Structure	Scattering Cross Section
O_1	$\bar{q}\gamma^\mu q\bar{\chi}\gamma_\mu\chi$	Spin Independent	$\frac{9g_V^2 g_\chi^2 M_n^2 M_\chi^2}{\pi M_{Z'}^4 (M_n+M_\chi)^2}$
O_2	$\bar{q}\gamma^\mu q\bar{\chi}\gamma_\mu\gamma_5\chi$	Spin Independent	$\sim v^2$
O_3	$\bar{q}\gamma^\mu\gamma_5 q\bar{\chi}\gamma_\mu\chi$	Spin Dependent	$\sim v^2$
O_4	$\bar{q}\gamma^\mu\gamma_5 q\bar{\chi}\gamma_\mu\gamma_5\chi$	Spin Dependent	$\frac{3g_A^2 g_\chi^2 (\Delta\Sigma)^2 M_n^2 M_\chi^2}{\pi M_{Z'}^4 (M_n+M_\chi)^2}$

Farinaldo Queiroz et al, arXiv:1312.5281

Z' Portal

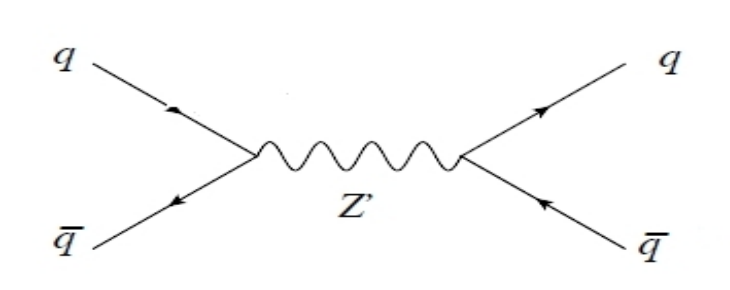


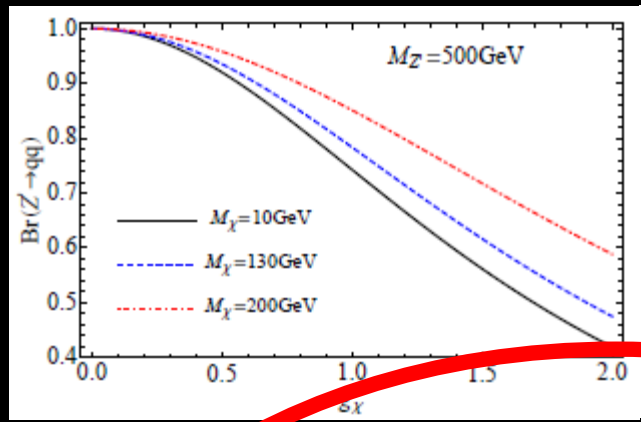
Annihilation into qq (all flavors) induce roughly the same gamma-ray espectrum

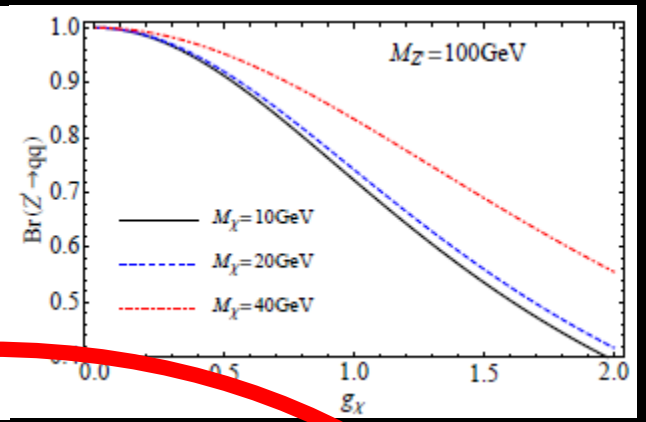
We can sum up the annihilation cross sections into all quark flavors and compare with the Fermi-LAT Collab arxiv:1310.0828 and Dan Hooper&Farinaldo Queiroz arXiv:1209.3015.

Dark Matter Search Based on Dijet Data

$p\bar{p} \to Z' \to jj$ $\quad$ $pp \to Z' \to jj$







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

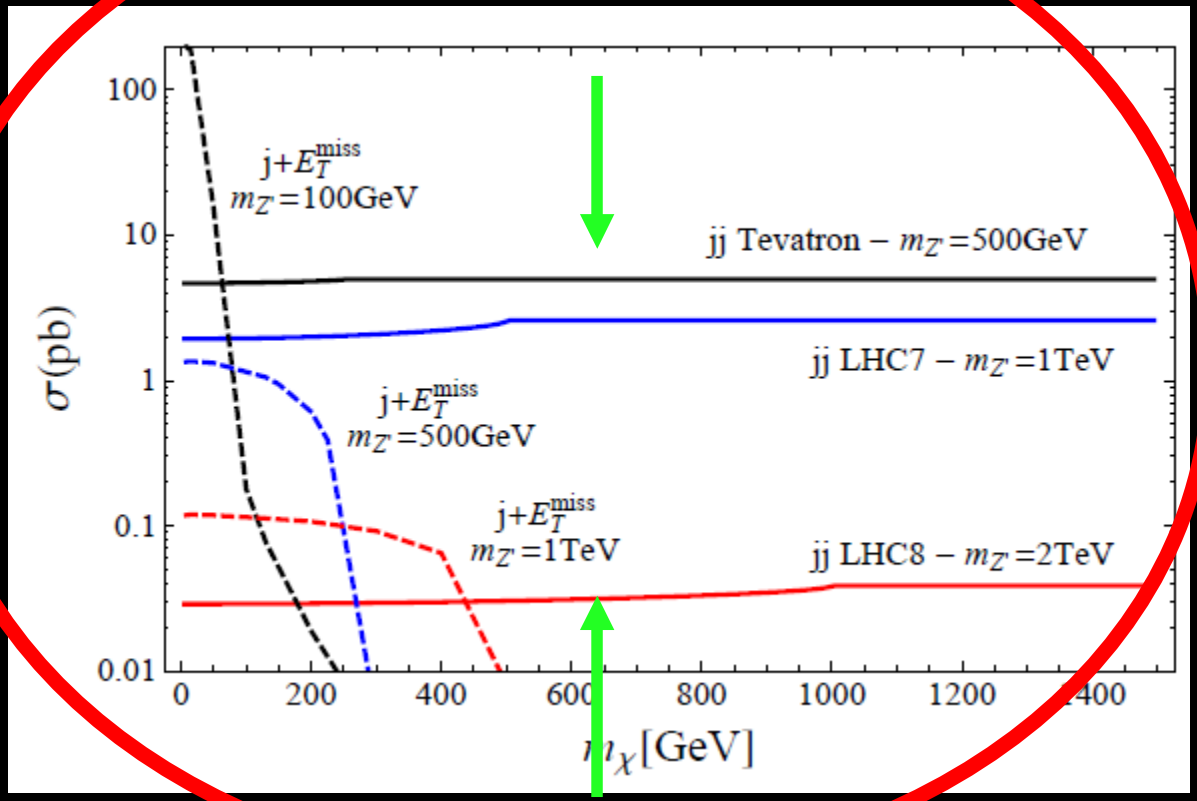
LHC andTEVATRON have been searching For resonances in di-jet events with null results until now

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' → q q) increases as M_χ approaches MZ' /2, up until

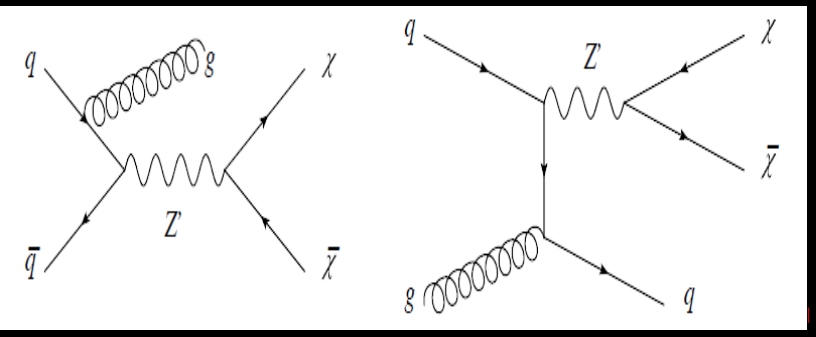
$$BR(Z' \to q\bar{q}) + BR(Z' \to \chi\bar{\chi}) = 1$$

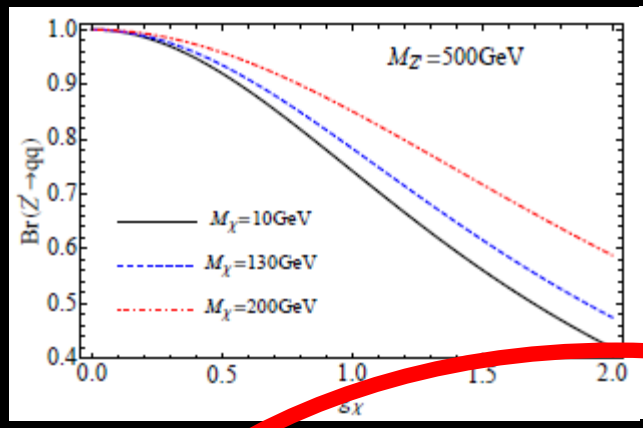
Decreasing the coupling between the DM and Z' increases the branching faction into quarks.

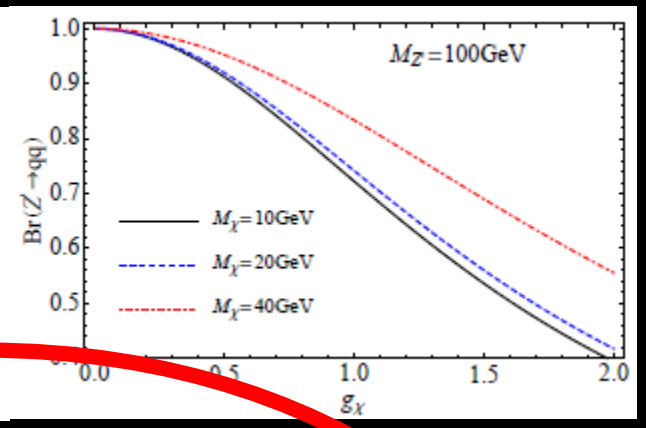


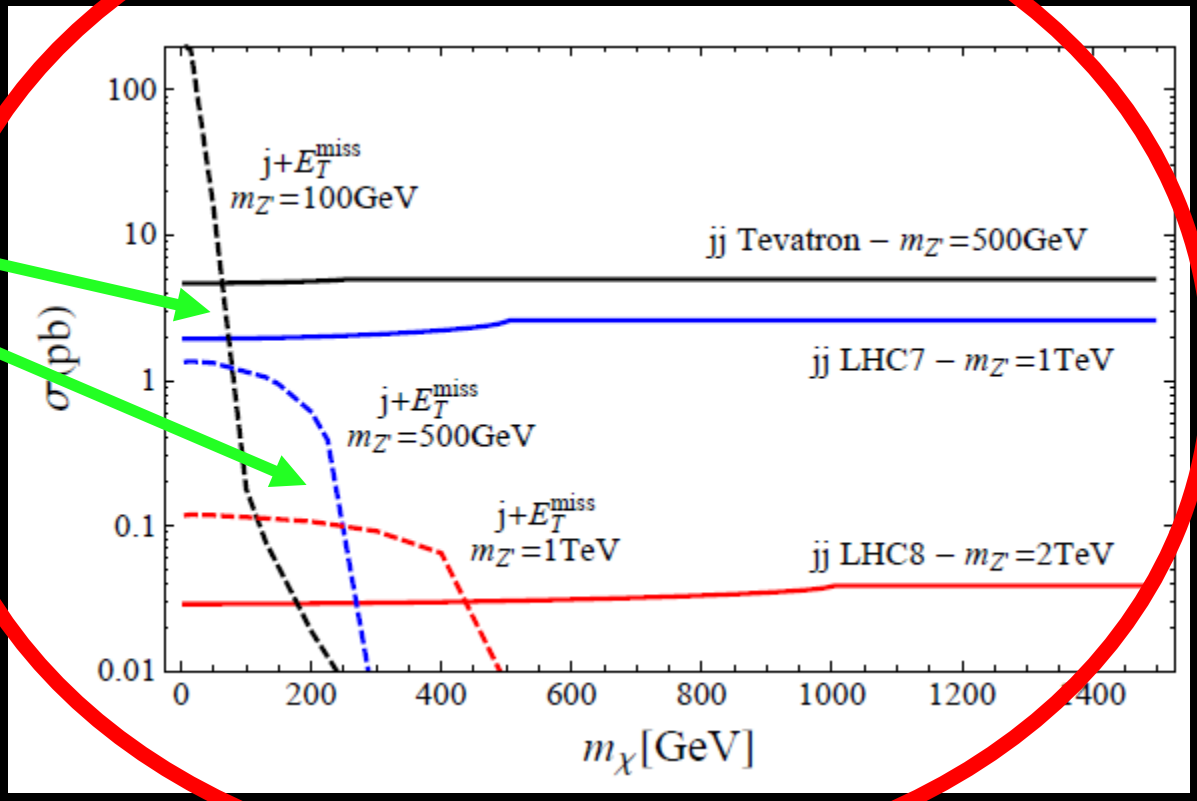
Dark Matter Search Based on Mono-Jet Data

$$pp \to Z' + j \to \chi\bar{\chi} + j \to \not{E}_T + j$$









The dark matter mass and couplings are important

For a fixed Z'mass, the branching ratio BR(Z' → q q) increases as M_χ approaches MZ' /2, up until

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

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

Dark Matter Complementarity

8GeV WIMP in light of DAMA, CDMS, CoGeNT and CRESST

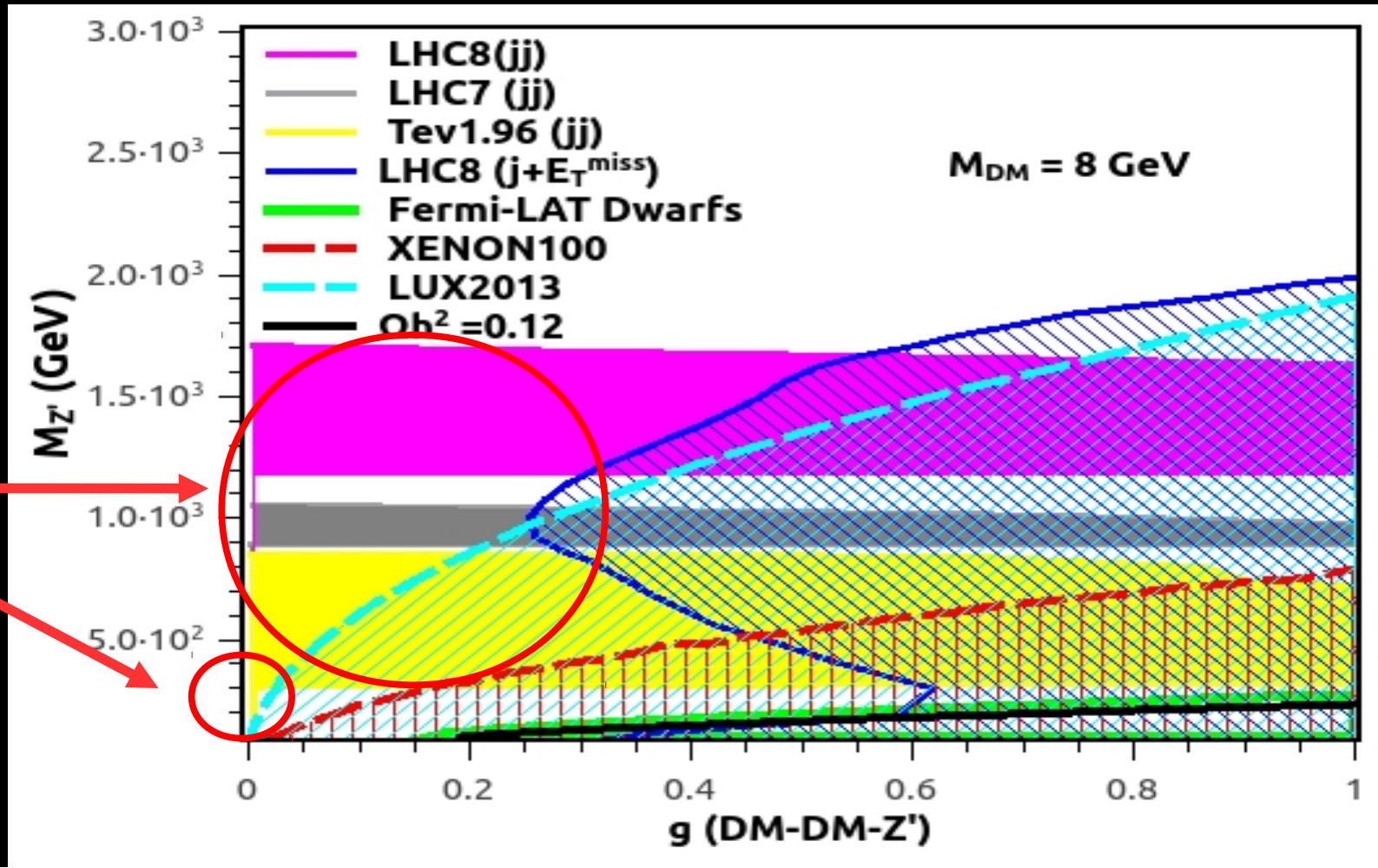
We're doomed

Combining colliders, direct and indirect detection bounds

Assuming the
Z' = Z

Viable region

Otherwise
Mz' >1.7 TeV



Dark Matter Complementarity

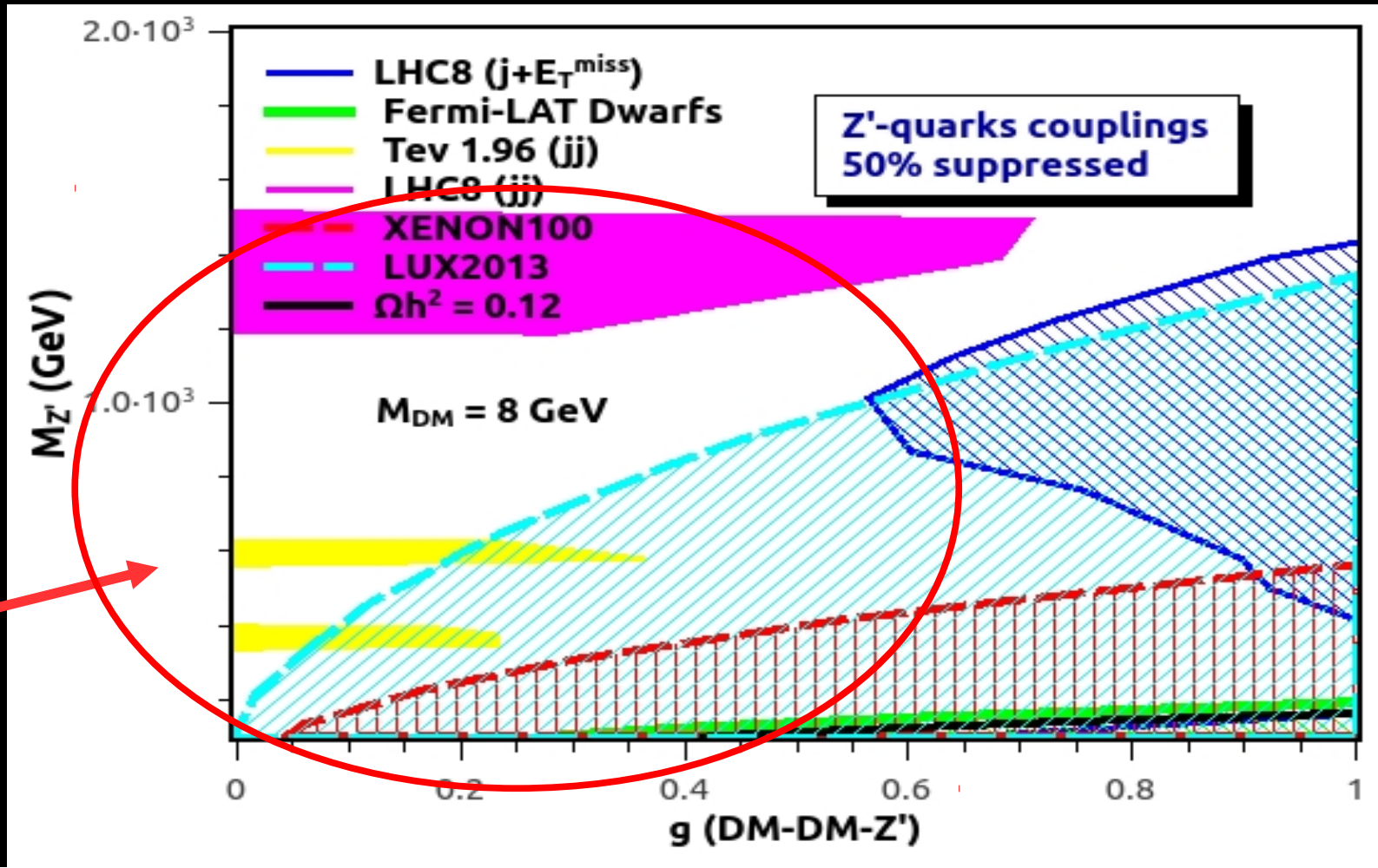
8GeV WIMP in light of DAMA, CDMS, CoGeNT and CRESST

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

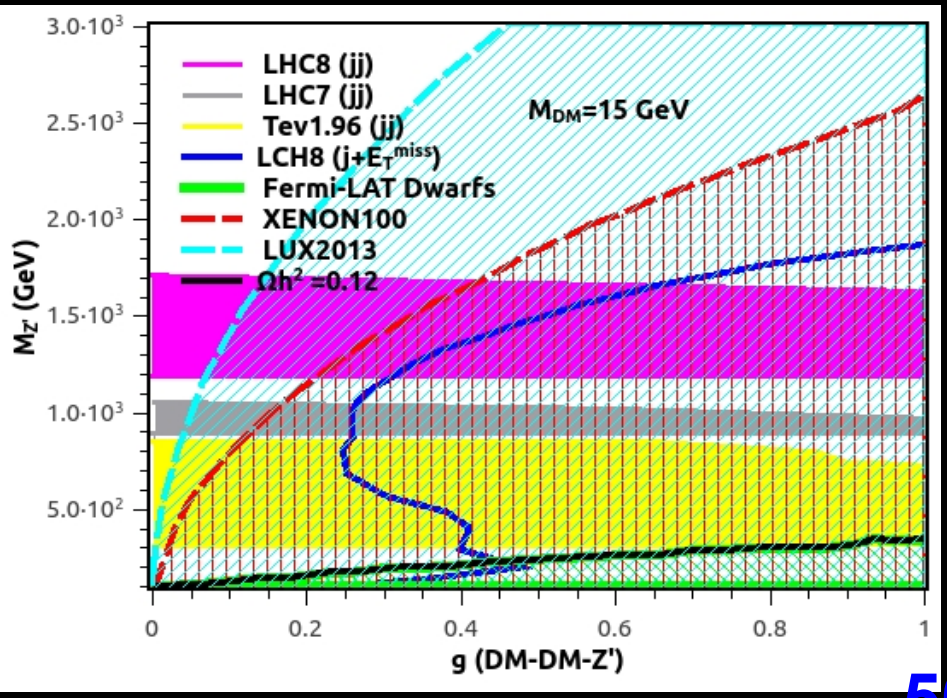
Viable region

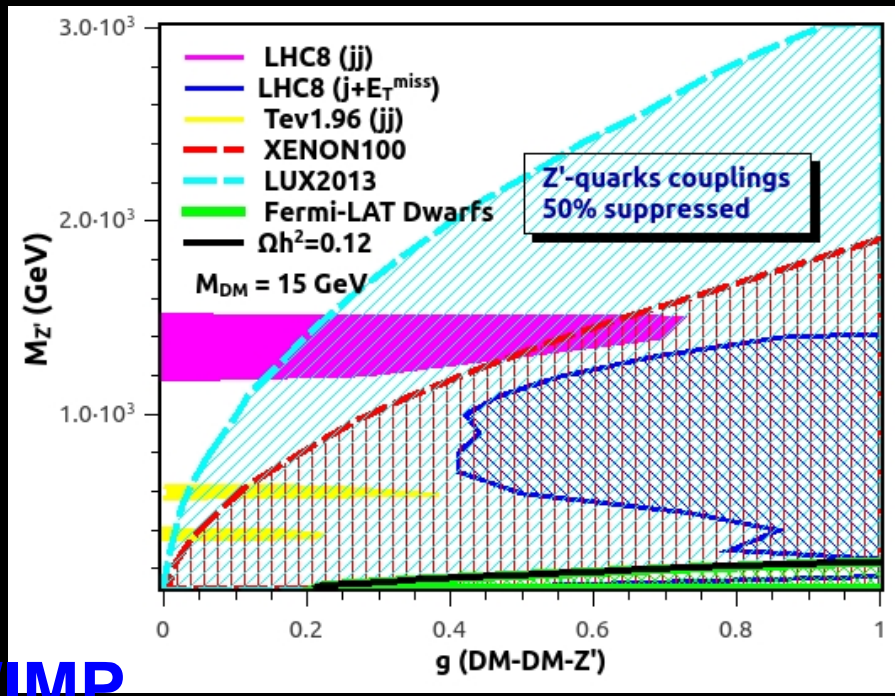
Combining colliders, direct and indirect detection bounds



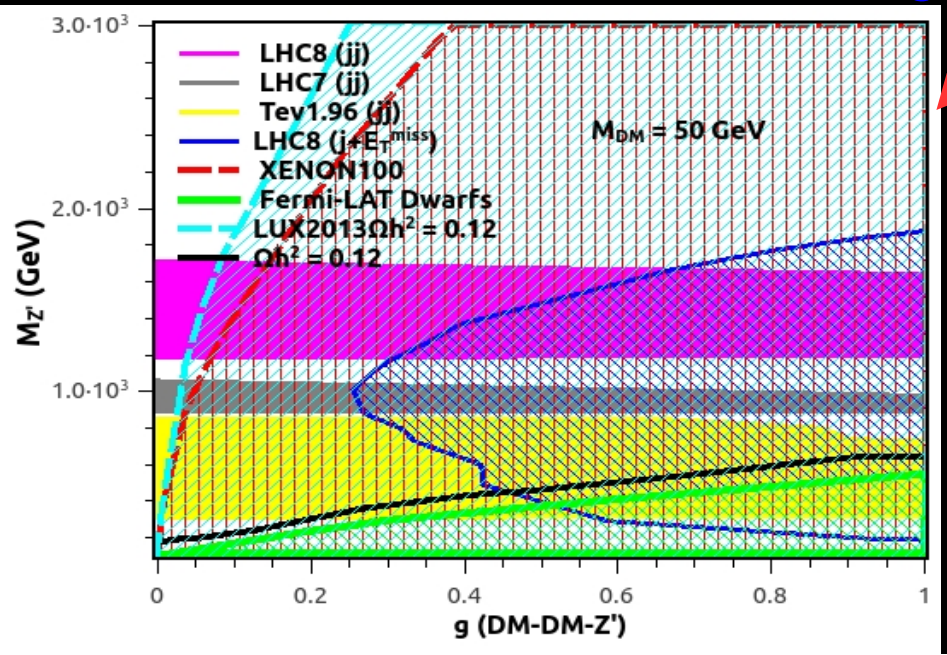
Dark Matter Complementarity

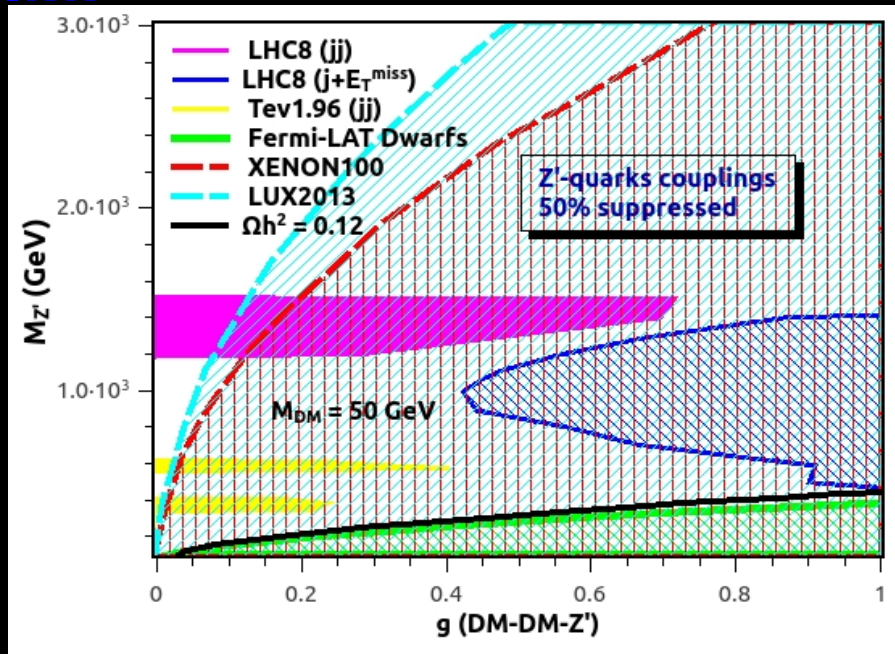
15 GeV WIMP in light of CDMS-Si Excess Events





50 GeV WIMP





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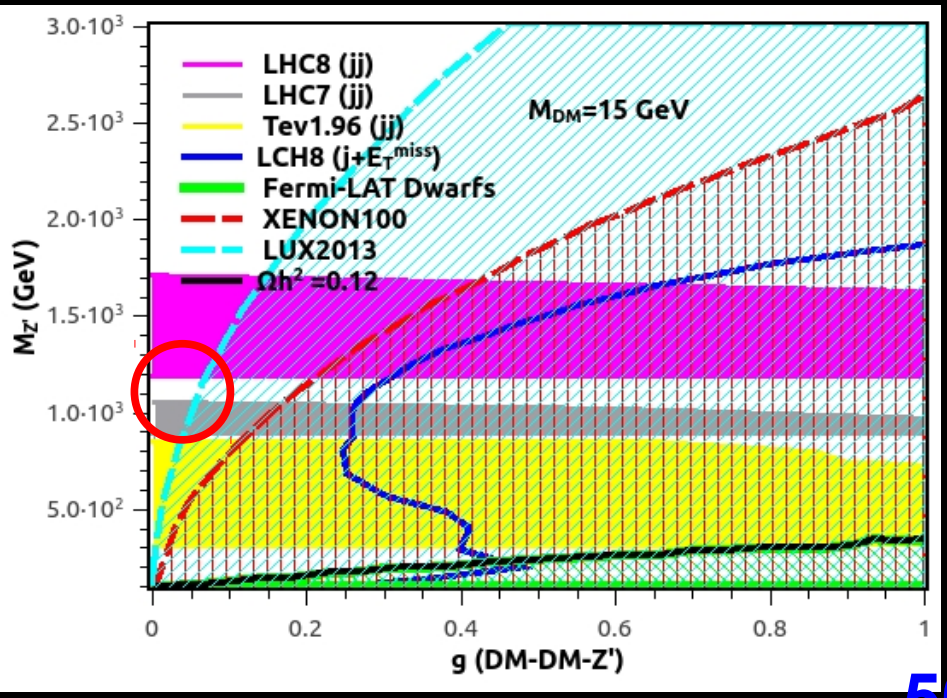

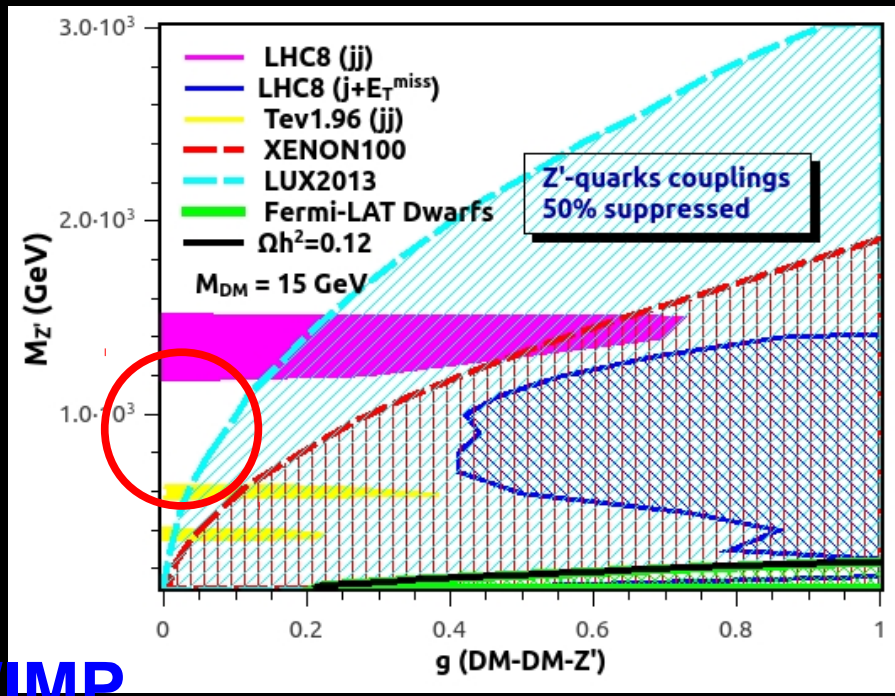

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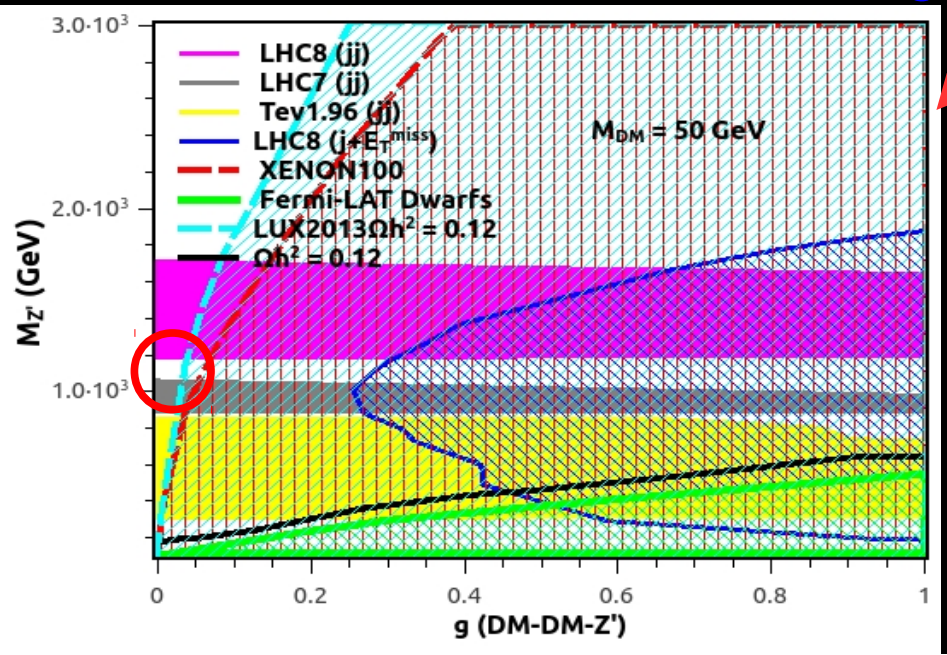
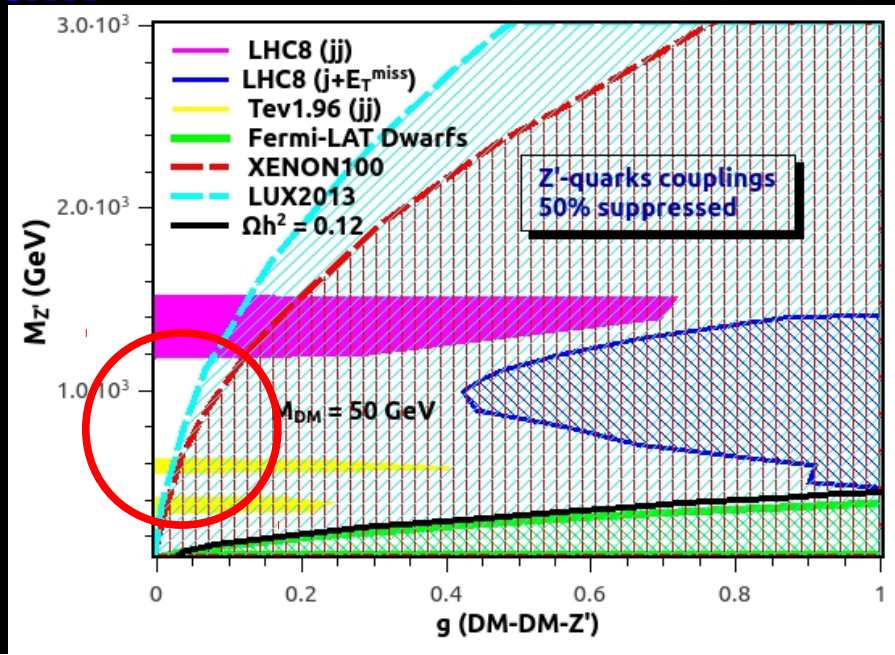
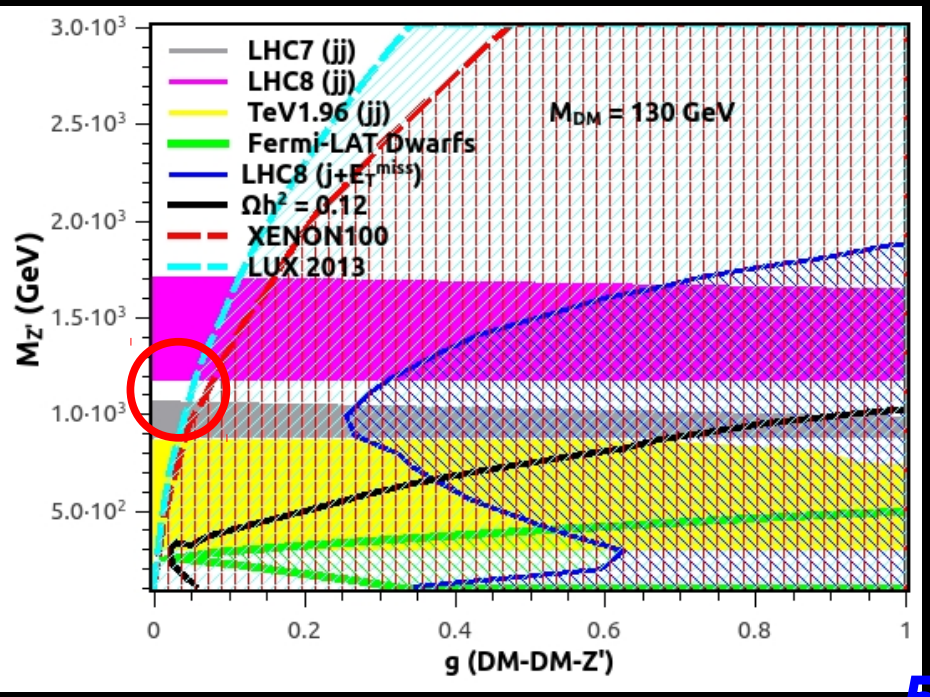
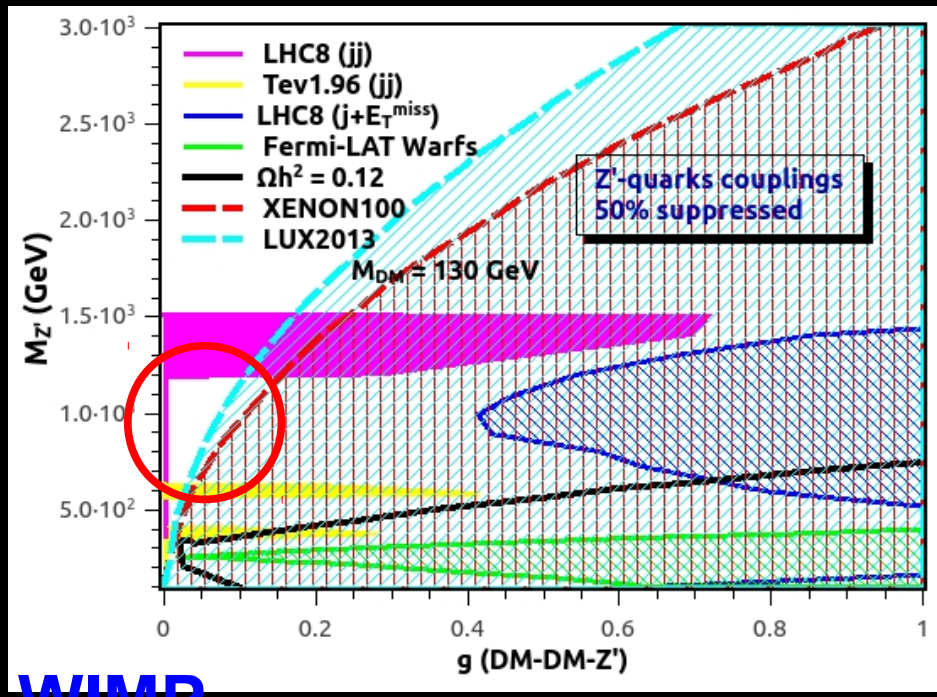




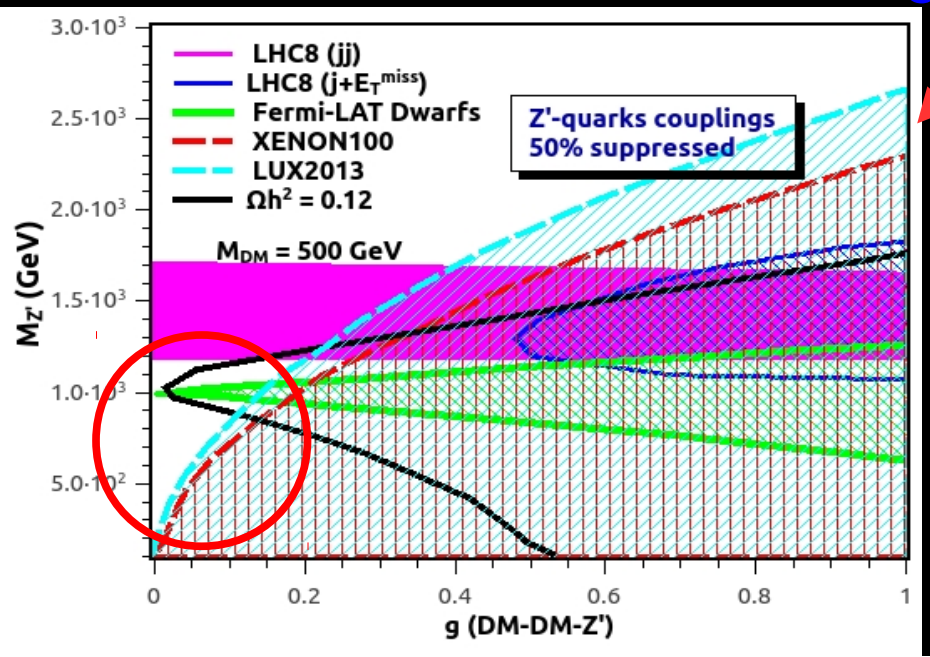
Dark Matter Complementarity

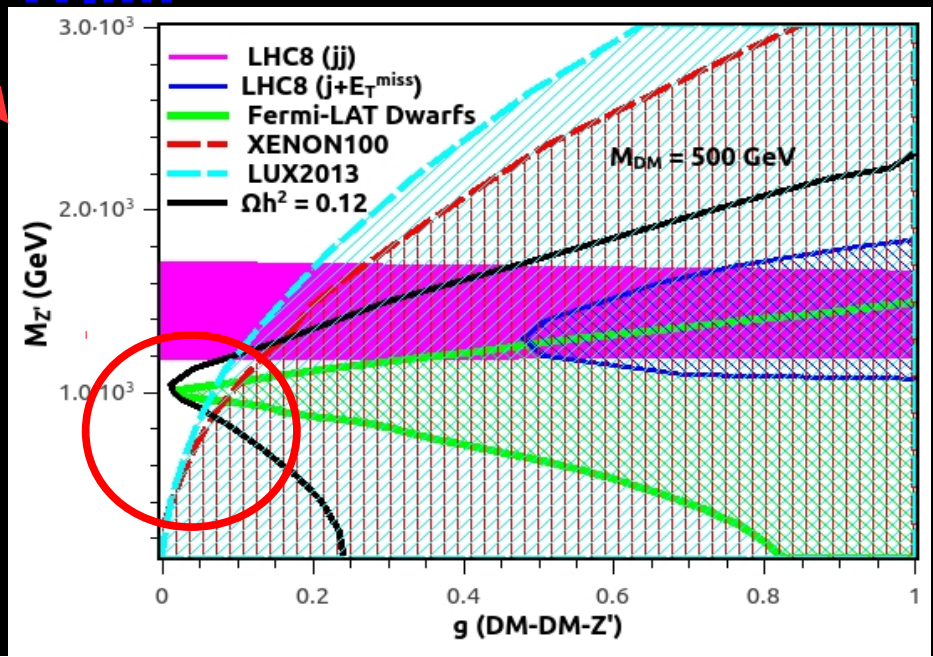
130 GeV WIMP





500 GeV WIMP





Conclusions

→ We investigated a particular incarnation of the Z' portal: Leptophobic

→ A high degree of complementarity at several different levels:

1. Direct x indirect dark matter searches

2. Dark matter searches x Collider studies

3. Tevatron x LHC searches

4. Mono-Jet x Di-jet searches

→ Near resonances the Z' portal is compatible with other searches/bounds.

Farinaldo Queiroz et al, arXiv:1312.5281

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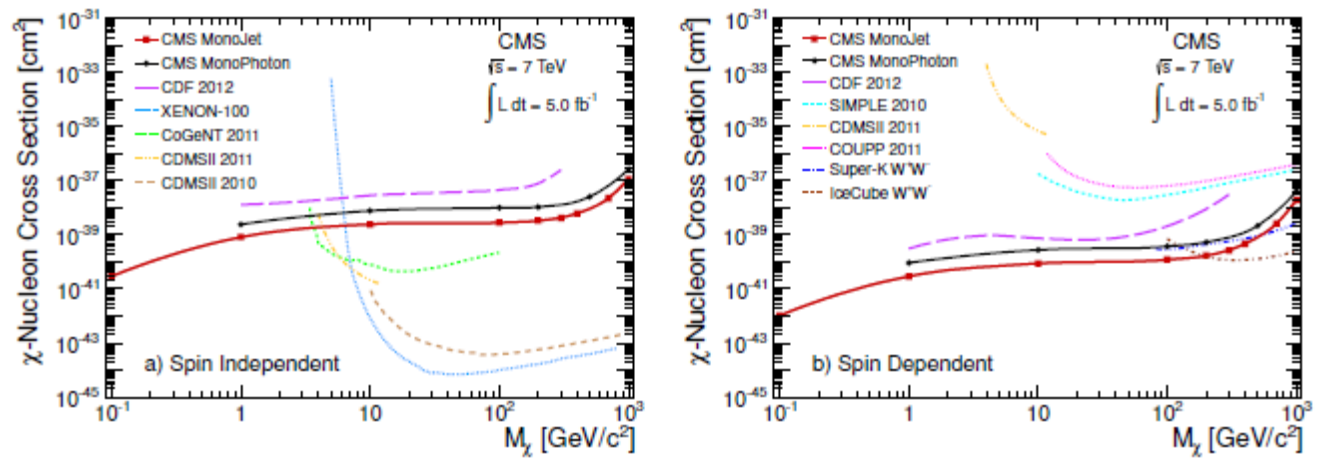
Thank you!

Farinaldo Queiroz et al, arXiv:1312.5281

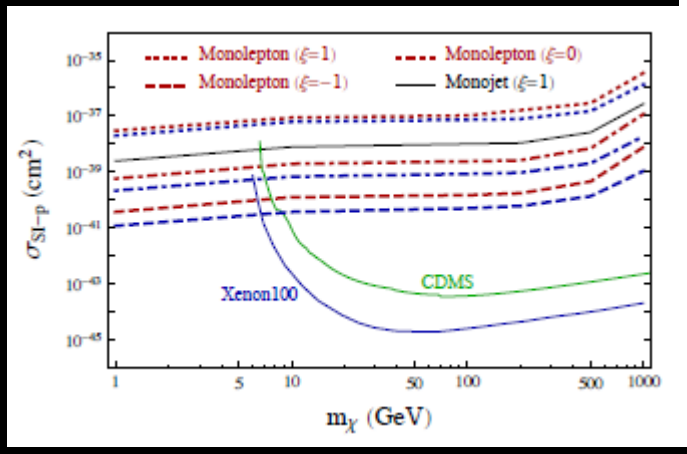
Backup Slide

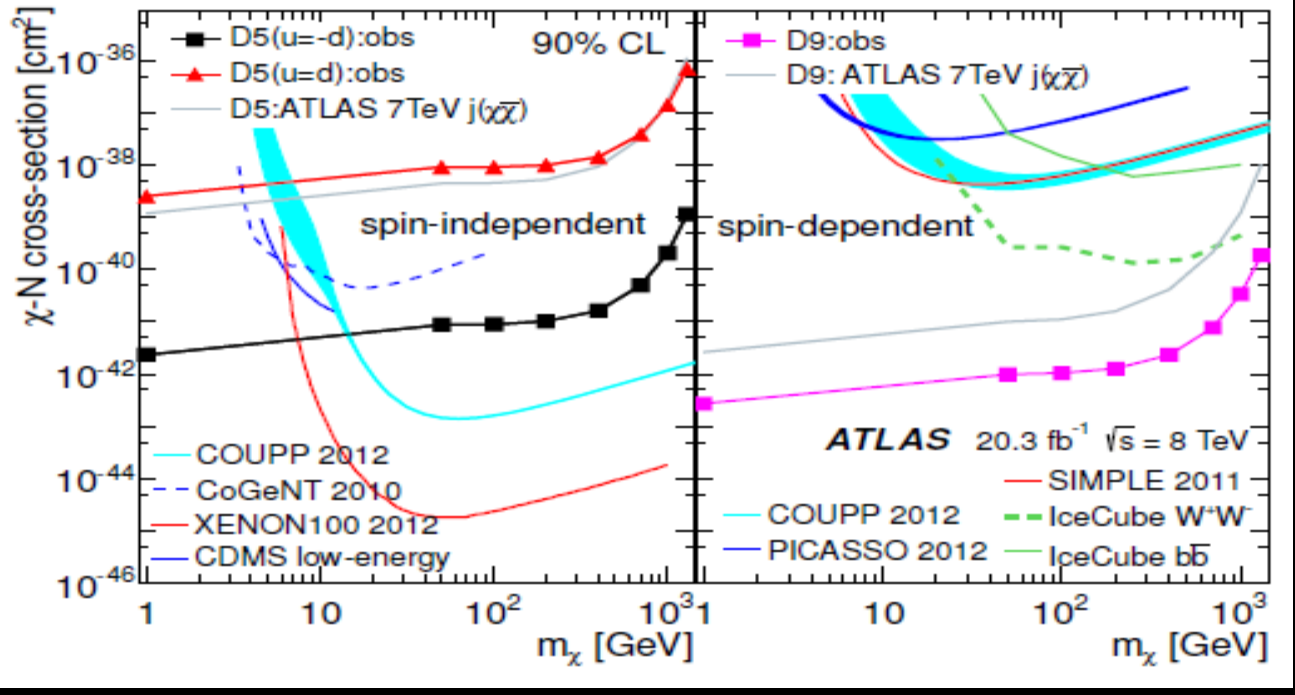
Mono-X Searches

Mono-photon



Mono-Z/W

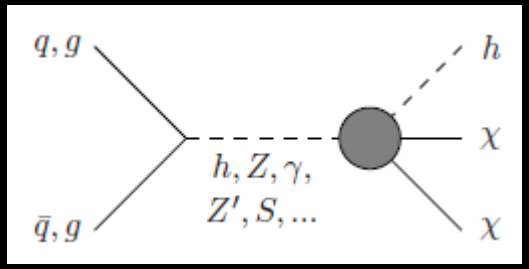


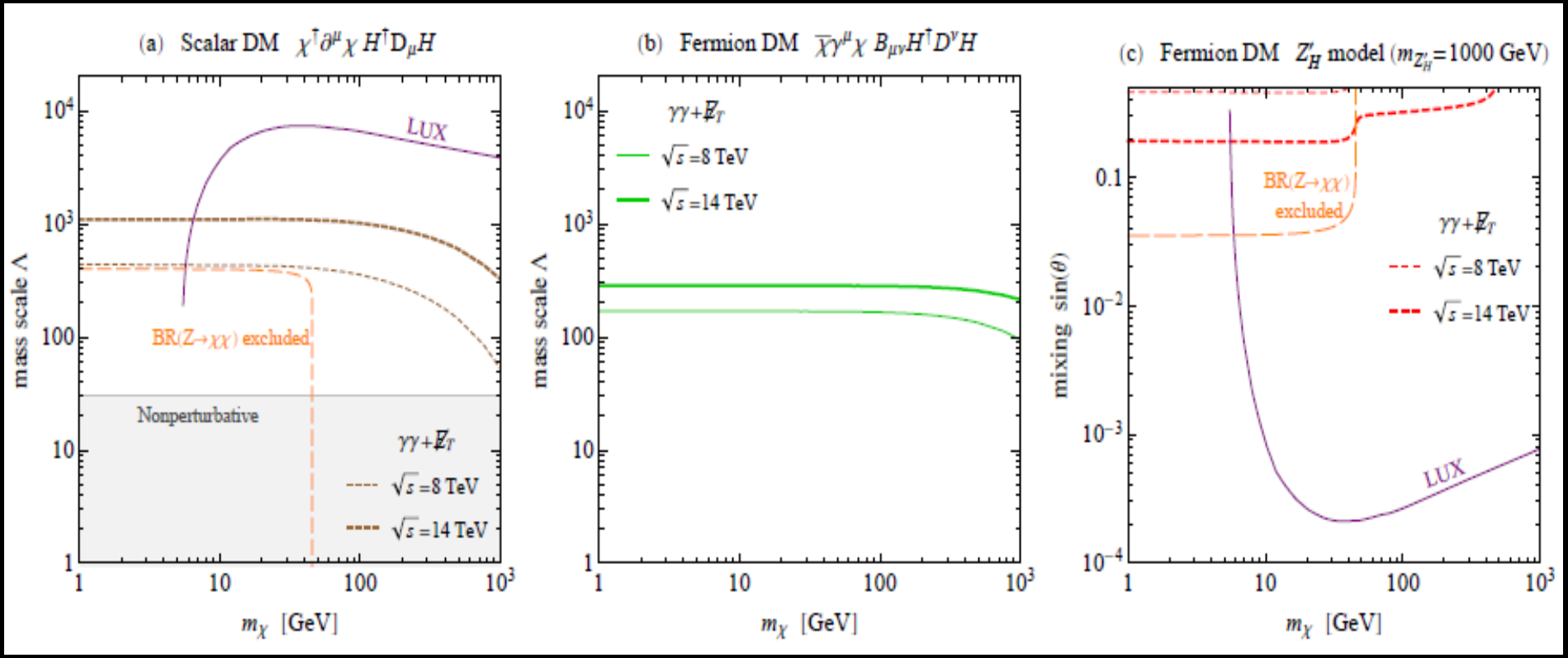


Farinaldo Queiroz et al, arXiv:1312.5281

Backup Slide

Mono-H





Michael Mulhearn,Daniel Whiteson et al, arxiv:1312.2592