Z'-explorer 2.0: unraveling the dark side.

arXiv: 2109.13194, 2005.05194

Z'-explorer collaboration: E. Álvarez, M. Estévez, VML, R. Sandá Seoane, J. Zurita.

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Z' boson and searches.

-Z' bosons are common in BSM theories (extra U(1)): U'(1), B-L, String theory...

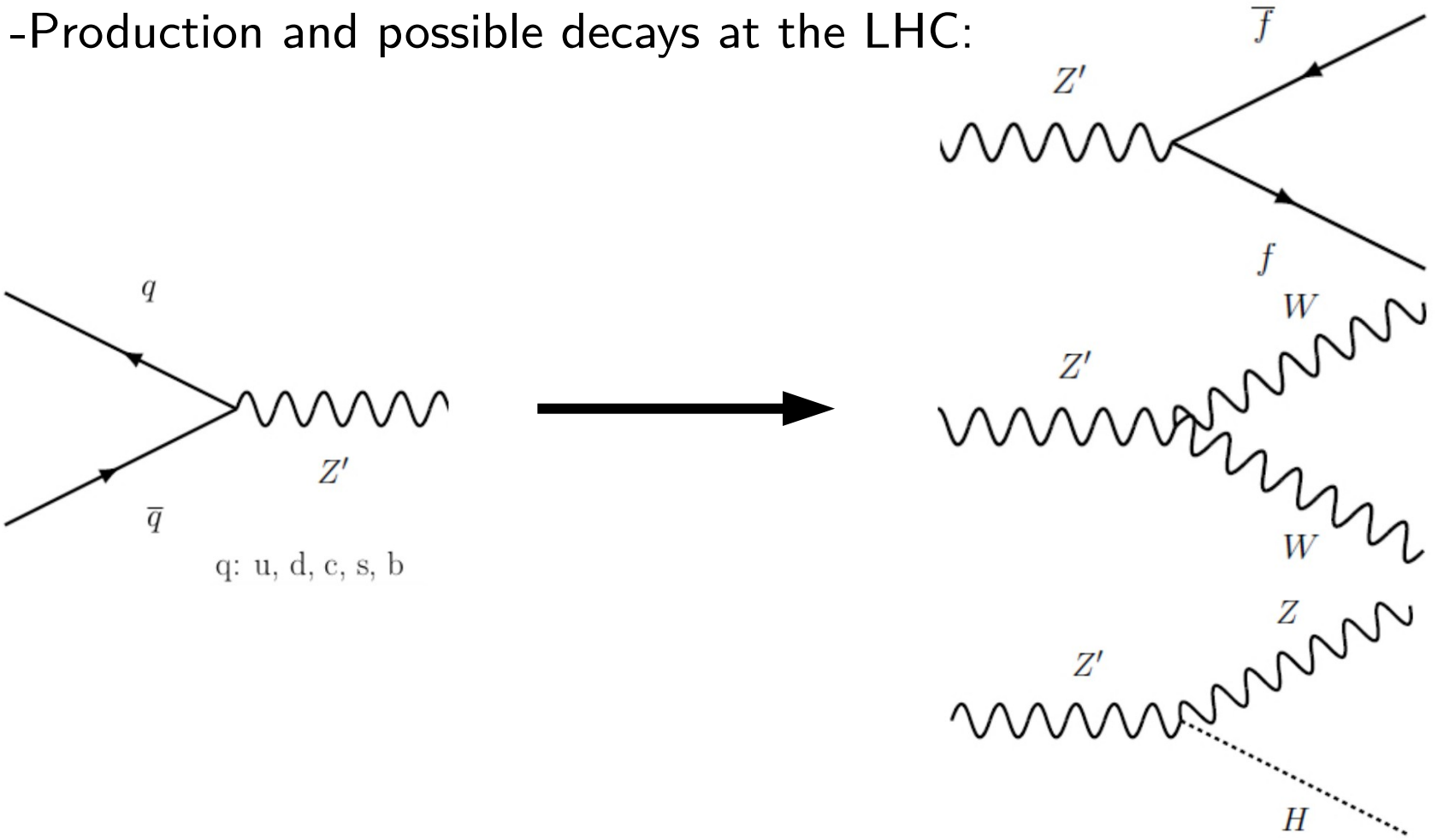
-Phenomenologically interesting: DM mediator, new signatures...

-Its coupling to SM particles determined by the specific model.

-If the Z' couples to quarks then it is possible to produce it at the LHC.

Z' boson and searches.

-Production and possible decays at the LHC:



Z' boson and searches.

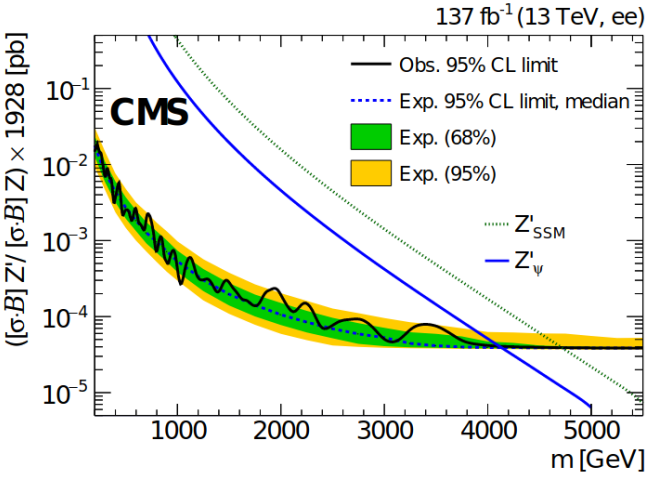
At the LHC, there are both ATLAS and CMS searches looking for Z'.

- They reach the TeV scale.
- Different visible channels: ee, $\mu\mu$, $\tau\tau$, jj, bb, tt, Zh, WW.

The sensitivity of a decay channel depends on:

- Energy scale of the resonance.
- Branching ratios.
- Backgrounds.
- Coupling structure.
- Acceptance and efficiencies.

Z' boson and searches.



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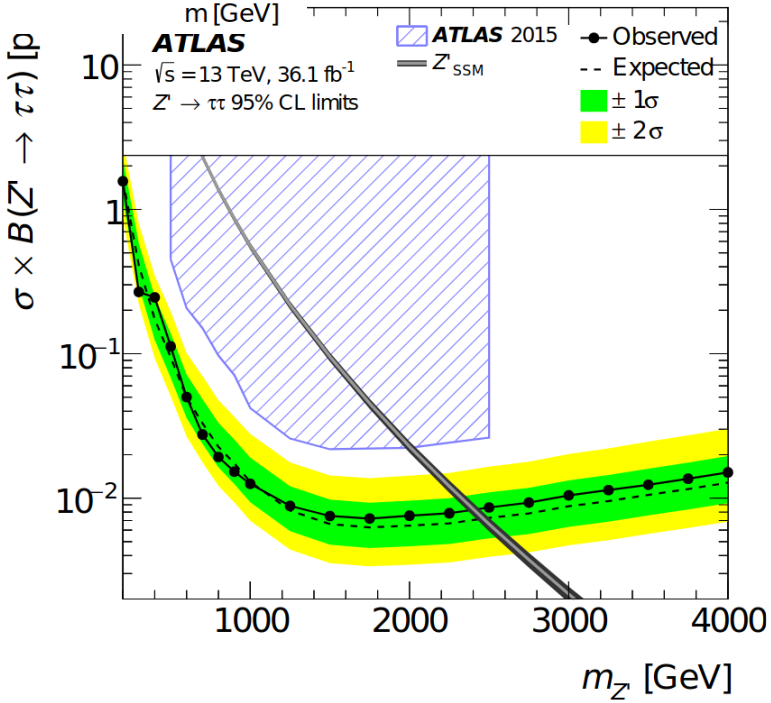

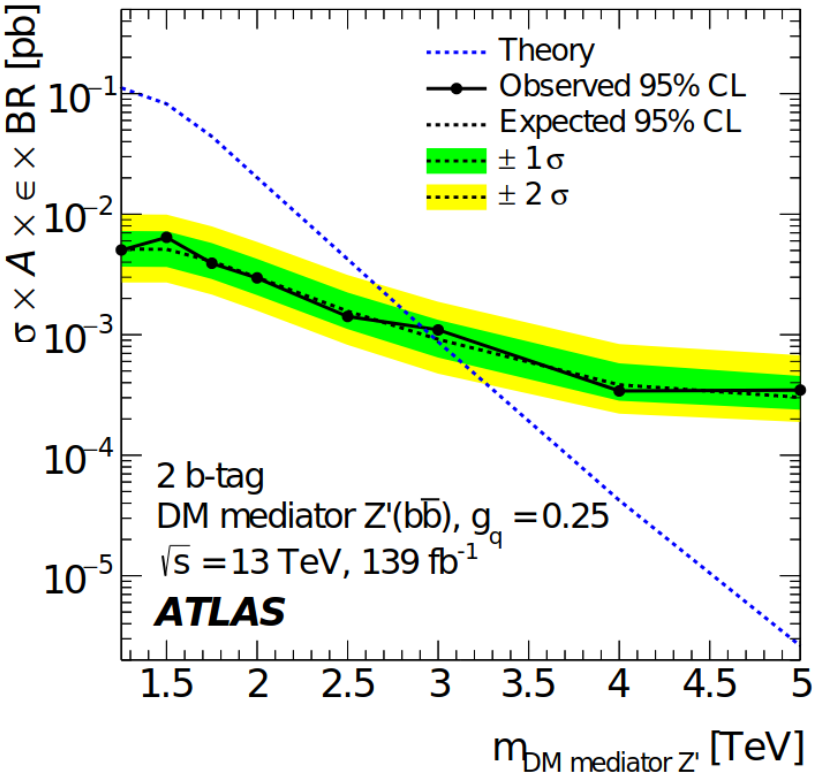

Z' boson and searches.

At the LHC, there are both ATLAS and CMS searches looking for Z'.

- They reach the TeV scale.
- D

Need to quickly compare the sensitivity of all channels at a fixed $M_{Z'}$

The

- E
- Branching ratios.
- Backgrounds.
- Coupling structure.
- Acceptance and efficiencies.

Z'-explorer 2.0.

Z'-explorer 2.0: reconnoitering the dark matter landscape

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arXiv: 2019.13194

Z'-explorer: A simple tool to probe Z' models against LHC data

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https://github.com/ro-sanda/Z-explorer-2.0
https://gitlab.com/v.martin.lozano/Z-explorer-2.0

Z'-explorer.

Z'-explorer software (runs on C++) is quick and simple to use. Incard (text file) must provide for each benchmark point (BP) in the BSM parameter space:

$$M_{Z'}\, g_{q_L}\, g_{q_R}\, g_{\ell_L}\, g_{\ell_R}\, \Gamma_{\nu\nu}\, \Gamma_{WW}\, \Gamma_{Zh}\, m_\chi\, g_{\chi L}\, g_{\chi R} \Gamma_{XX}$$

After running the program, the output is written in a text file and it gives the strength of the signal of each channel for each point:

$$S_{jj}\, S_{bb}\, S_{tt}\, S_{ee}\, S_{\mu\mu}\, S_{\tau\tau}\, S_{\nu\nu}\, S_{WW}\, S_{Zh}\, S_{\chi\chi}\, \Gamma_{Z'}\, \mathrm{WARNING} : \Gamma_{Z'} > 5\,\mathrm{GeV}$$

$$\mathcal{S} = \frac{\sigma_{pred}}{\sigma_{lim}}$$

$\sigma_{pred} = \sigma \times BR$

$\sigma_{lim} = \sigma \times BR$ 95% *CL UL*

$S > 1$ (in a given channel)
BP experimentally excluded

$S < 1$ (in all channels)
BP not excluded. Largest S, most sensitive channel

Z'-explorer.

Production cross section ($\sigma_{pp->Z'}$): Sum of u, d, c, s, b contributions (calculated with MadGraph in the range $M_{Z'} \in [0.5, 8]$ TeV for $\sqrt{s} = 13$ TeV) and adjusted using the sum of the corresponding squared chiral couplings:

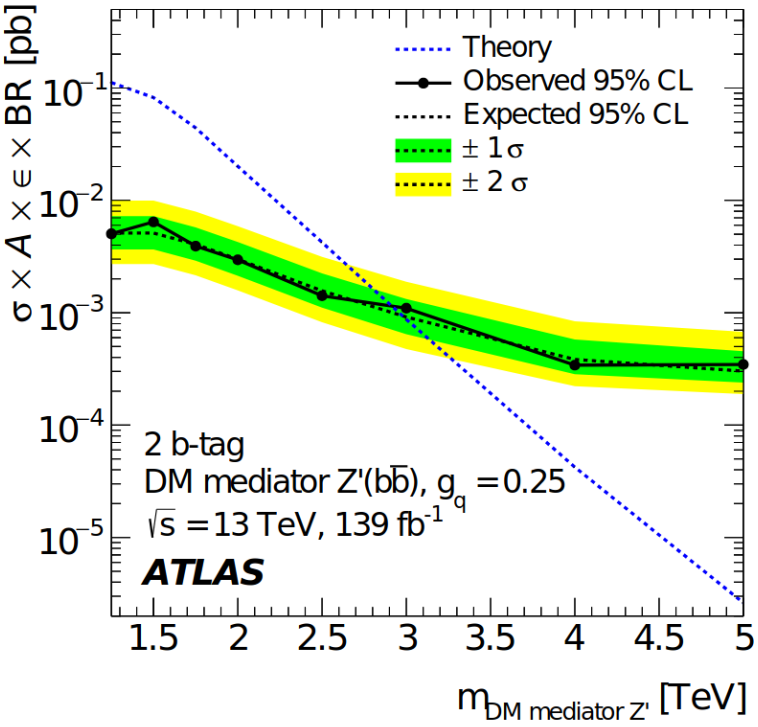
$$\sigma_{pp->Z'} = \sum_q \sigma^{g_q=1}_{q\bar{q}->Z'} \left[(g_q^R)^2 + (g_q^L)^2 \right]$$

Then in order to obtain the total cross section it computes

$$\sigma_{pred} = \sigma_{pp->Z'} \times BR(Z' -> XY)$$

Z'-explorer.

σ_{lim}: 95% C.L. expected upper limit $\sigma \times BR$ extracted from ATLAS and CMS results at $\sqrt{s} = 13$ TeV.



(1910.08447)

Channels included:

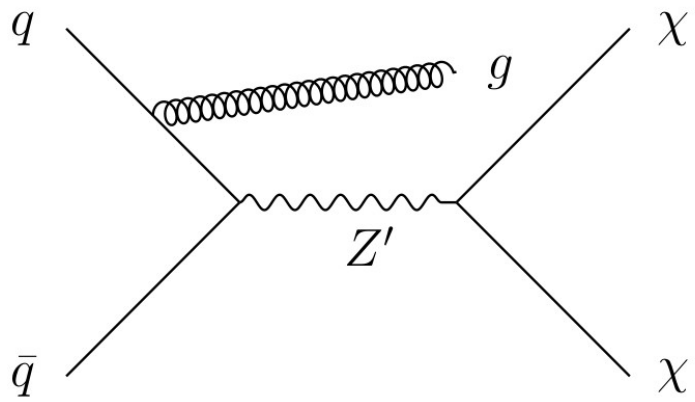
jj, ee, $\mu\mu$, $\tau\tau$, jj, bb, tt, Zh, WW

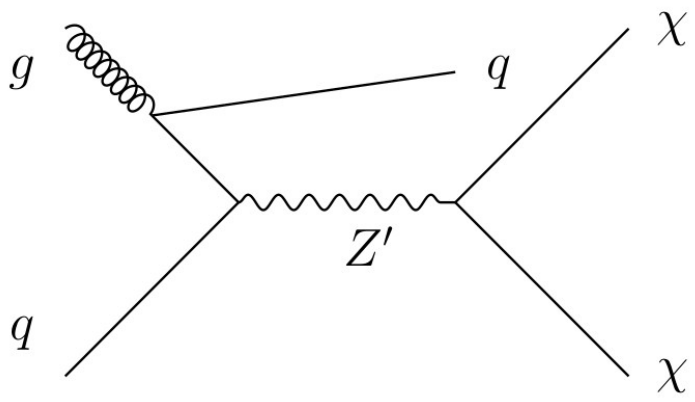
Finally we can compute:

$$\mathcal{S} = \frac{\sigma_{pred}}{\sigma_{lim}}$$

Z'-explorer.

Also, when considering the Z' as a dark matter mediator the mono-jet signature can be crucial in order to set bounds.



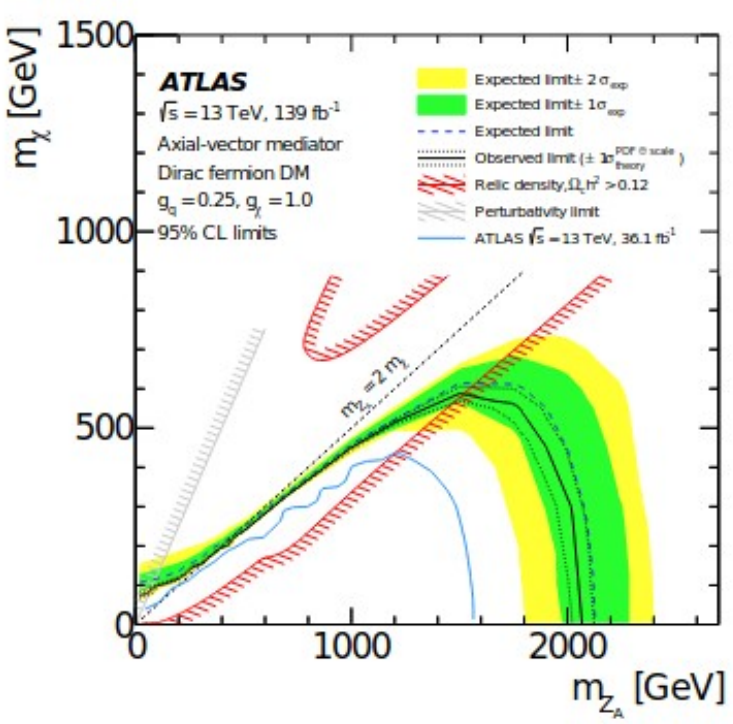


Z'-explorer.

Also, when considering the Z' as a dark matter mediator the mono-jet signature can be crucial in order to set bounds.

We have recasted the ATLAS mono-jet search:

$\longrightarrow$ Bounds for an axial-vector (Z_A) or vector (Z_V) dark matter mediator in the ($M_{Z'}$, m_χ) plane, with $g_\chi = 1$ and $g_q = 0.25$.



(2102.10874)

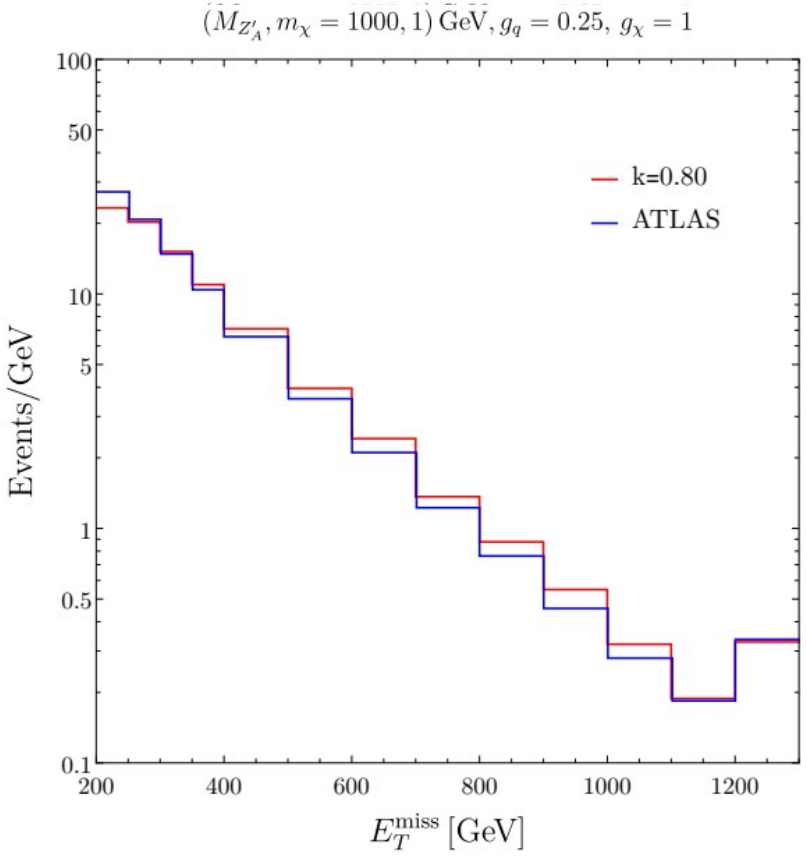
$$\mathcal{L} \supset -\sum_q g_q Z'_{A\mu} \bar{q}\gamma^\mu\gamma^5 q - g_\chi Z'_{A\mu} \bar{\chi}\gamma^\mu\gamma^5\chi$$

$\longrightarrow$ Event selection:

- $E_T^{miss} > 250$ GeV.
- Veto μ/e.
- $p_{T,j_1} > 250$ GeV, $|\eta_{j_1}| < 2.4$.
- $n_j \leqslant 4$, $p_{T,j} > 30$ GeV, $|\eta_j| < 2.8$, $\Delta\Phi(j, p_T^{miss}) > 0.4$.

Z'-explorer.

Simulations performed with MadGraph5_aMC@NLO, Pythia and Delphes (we used the UFO-model Dmsimp).



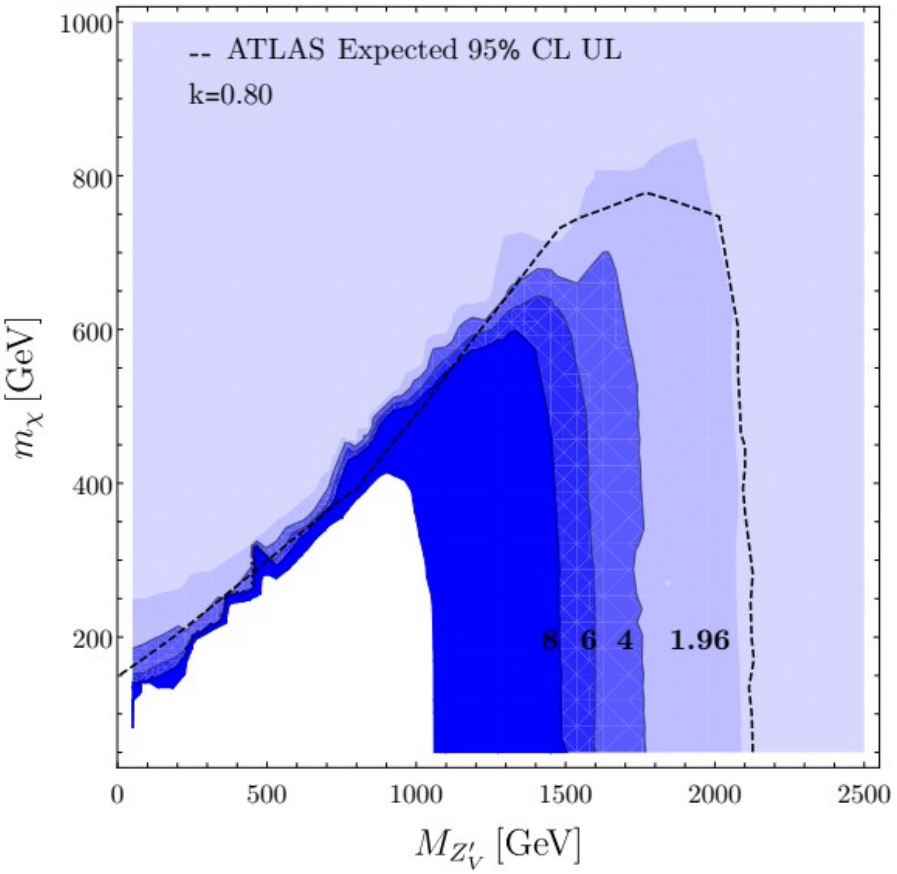
After event selection in order to match ATLAS distributions we need a k-factor of

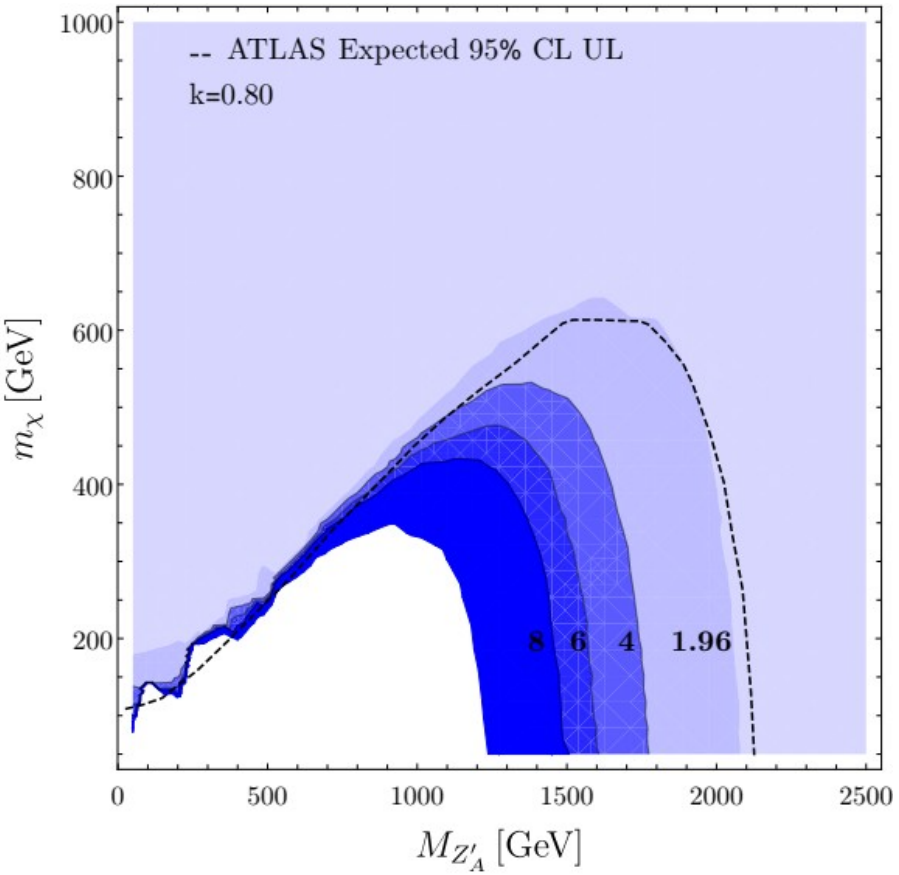
k=0.80

Z'-explorer.

We can now validate our analysis (including the k-factor) against ATLAS results to see how well is the performance.

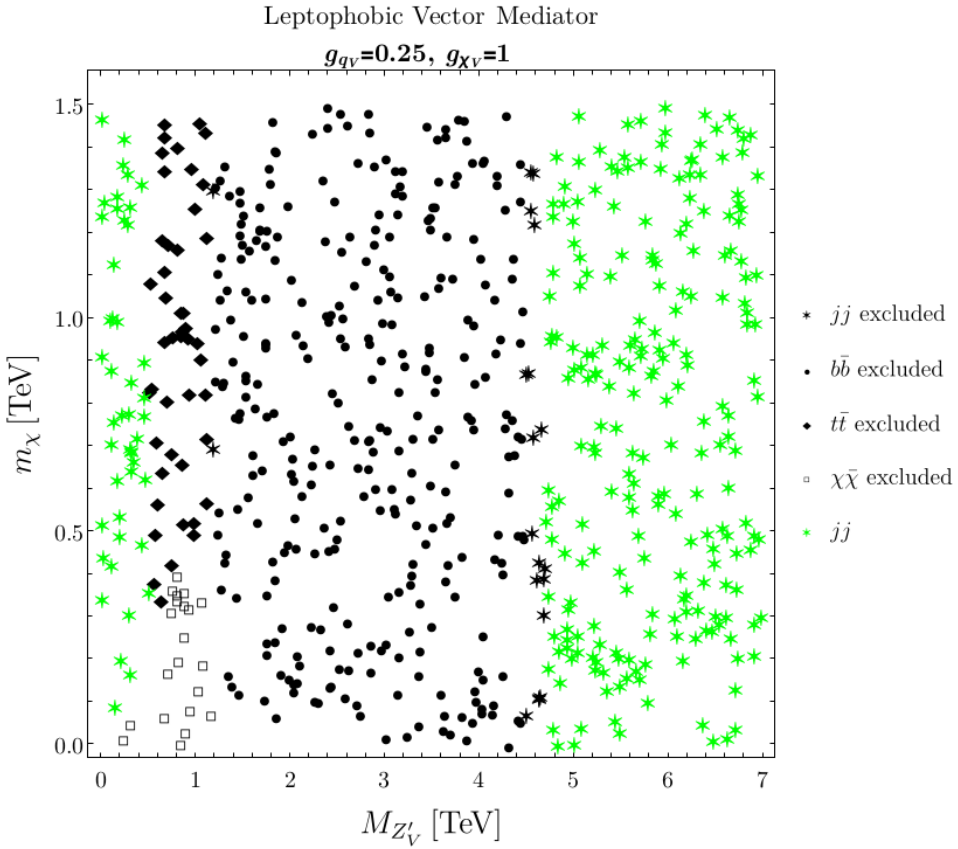
Our analysis matches pretty well the ATLAS monojet limits.

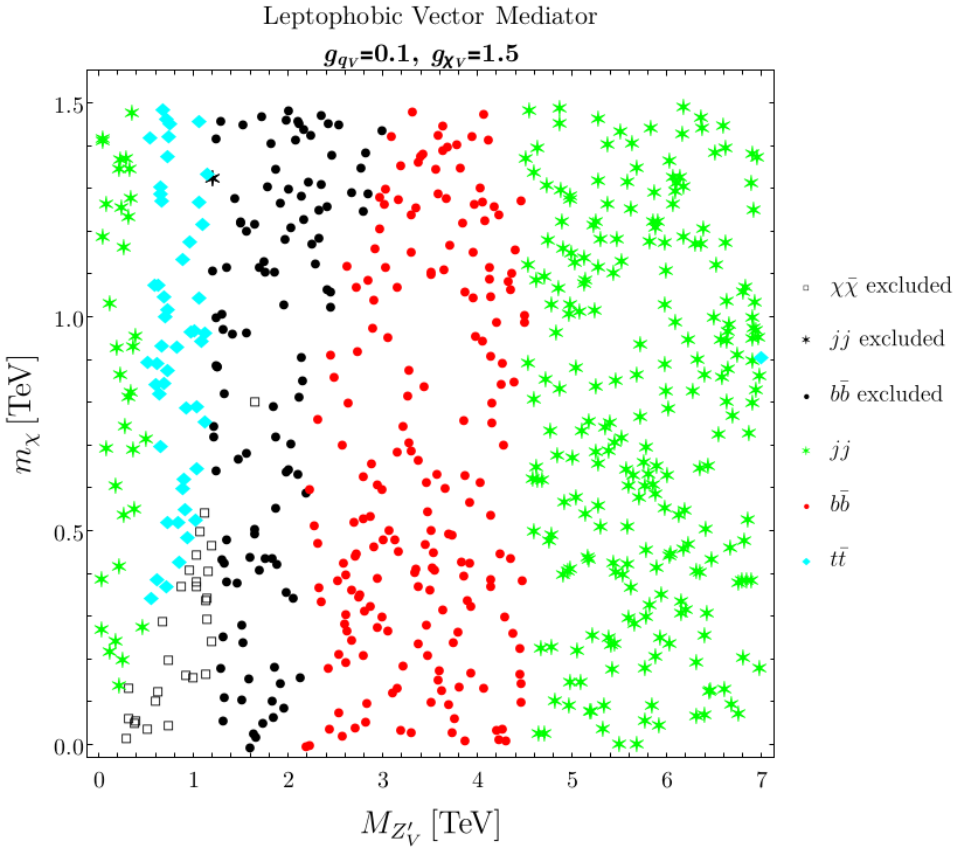




Results.

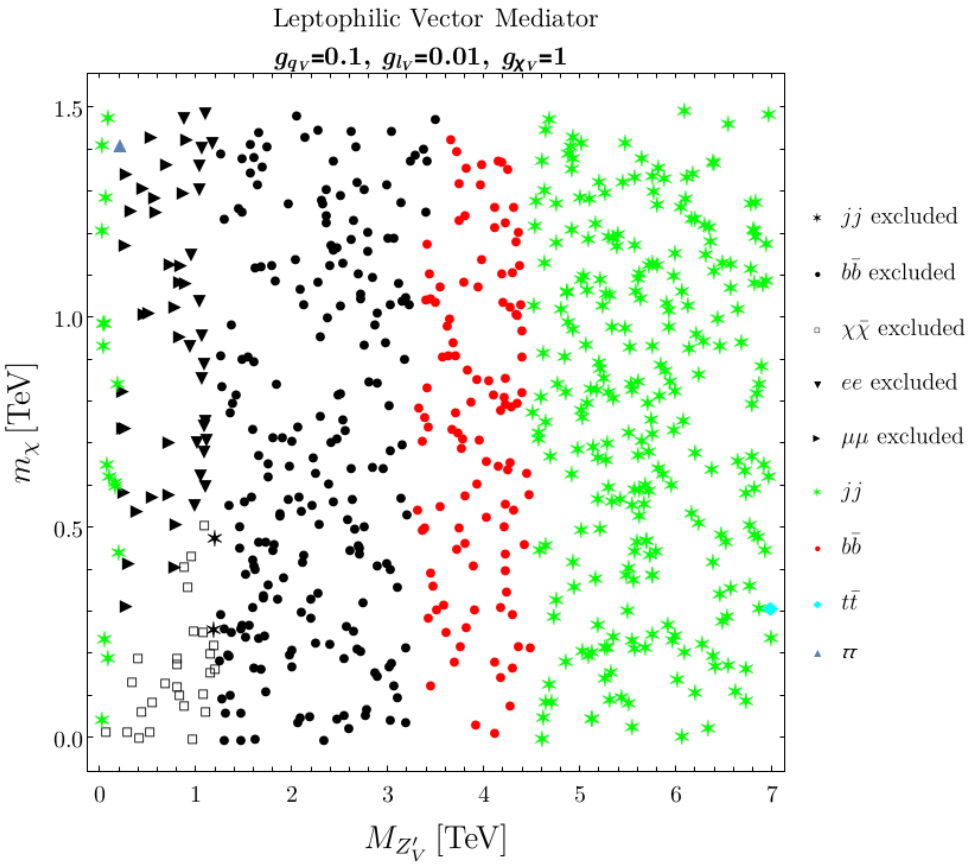
We set $g_l = 0$ so the Z' does not couple to leptons.

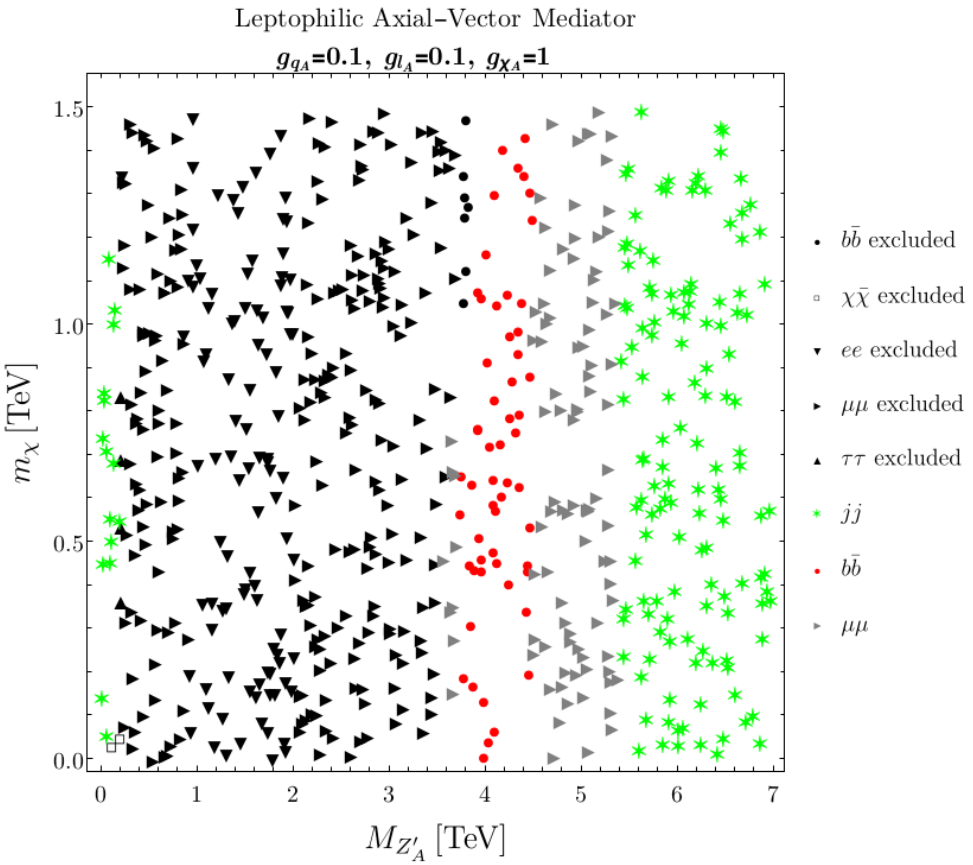




Results.

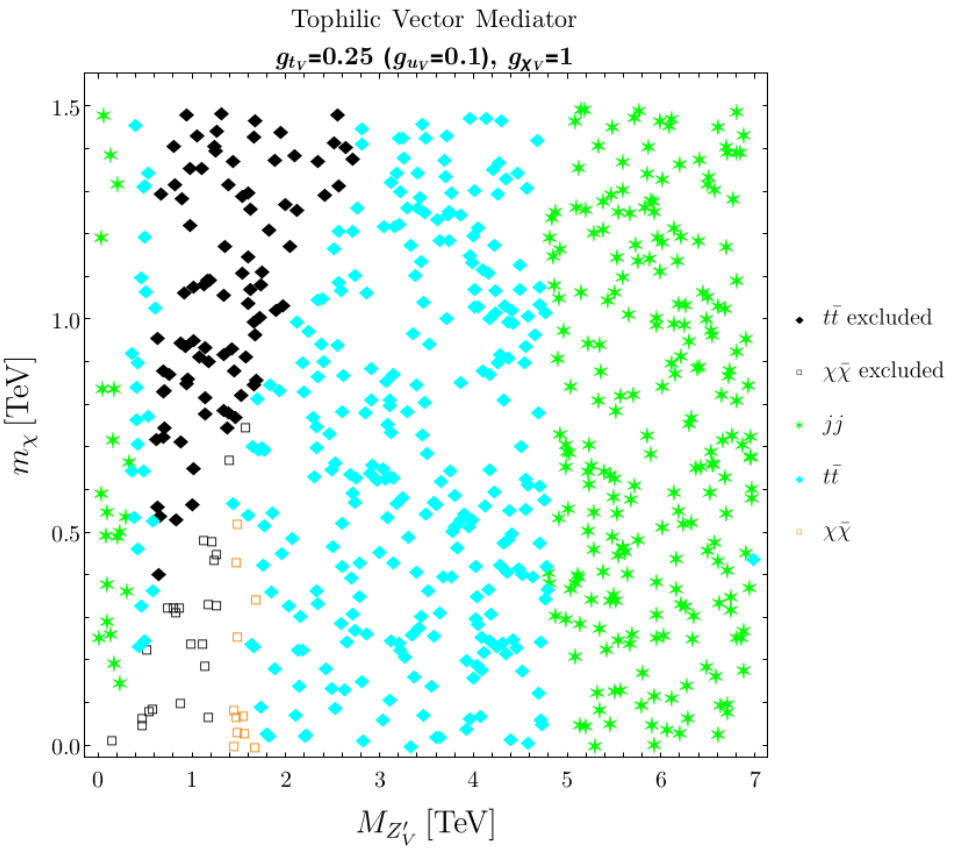
We allow the Z' to couple to both quarks and leptons.

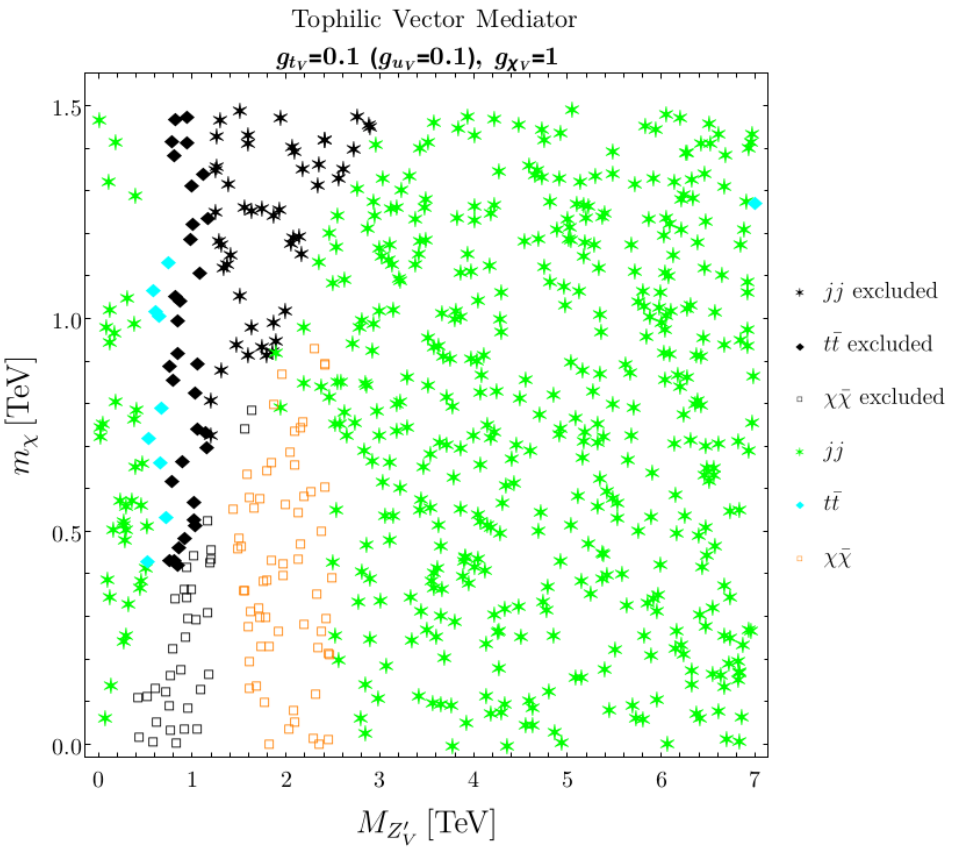




Results.

We set $g_l = 0$ so the Z' does not couple to leptons and we fix the couplings so the the Z' coupling to top quarks dominates.





Conclusions.

-Z'-explorer is able to set bounds on models with an extra U(1).

-It determines the most sensitive channel according to LHC searches.

-It includes all the dijet, dilepton and different Z' searches from ATLAS and CMS experiments.

-It also includes ATLAS mono-jet search at 139 fb^{-1} (first one) and it is validated with ATLAS results.

-Future: other mono-X searches, include computation of DM observables, finite width effects...

-All the information about Z'-explorer can be found here:
`https://github.com/ro-sanda/Z-explorer-2.0`
`https://gitlab.com/v.martin.lozano/Z-explorer-2.0`

Thank you!