Dilepton searches and Dark Matter

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Framework for DM searches at the LHC

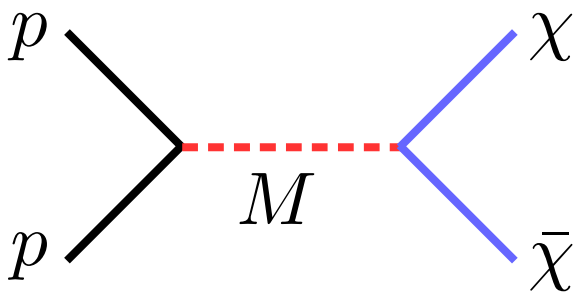
Simplified Models of Dark Matter: SM + **DM** + **Mediator**

Dirac fermion

vector or scalar

See Abdallah et al, 1506.03116
Abercombie et al, 1507.00966

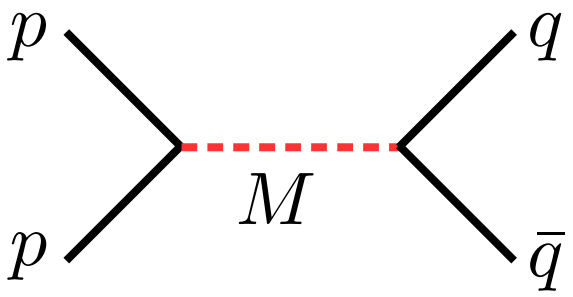
Production of DM:



Typical topology: MET + jet(s)

e.g. 1604.07773 (ATLAS)

Unavoidable by-product:



Topology: dijets

(considering so far resonant searches)

e.g. ATLAS-CONF-2016-069
ATLAS-CONF-2016-030

Including vector mediator couplings to leptons

Motivations:

- Challenging to find UV-completions without Z' couplings to leptons

  e.g. Arcadi, Mambrini, Tytgat, BZ, 1401.0221

  But see Ismail et al, 1609.02188 as counter-example

- Gauge invariance:

  Writing proper Z' interactions with the fermions leads to

$$q_H = q_{q_L} - q_{u_R} = q_{d_R} - q_{q_L}, q_{e_R} - q_{\ell_L}$$

  Non-zero axial couplings to quarks → non-zero axial couplings to leptons

  Kahlhoeffer, Schmidt-Hoberg, Schwetz, Vogl, 1510.02110

- Even for pure vector model, at least loop-induced couplings to leptons will be generated.

First Idea:

- Include dilepton searches for heavy narrow resonances (very constraining!)

  e.g. CMS-EXO-16-031

About the mediator width

Consider e.g. the axial model:

$$\mathcal{L}_{\text{axial-vector}} \supset -g_{\text{DM}} Z'_\mu \bar{\chi}\gamma^\mu\gamma_5\chi - g_q \sum_q Z'_\mu \bar{q}\gamma^\mu\gamma_5 q - g_\ell \sum_\ell Z'_\mu \bar{\ell}\gamma^\mu\gamma_5\ell$$

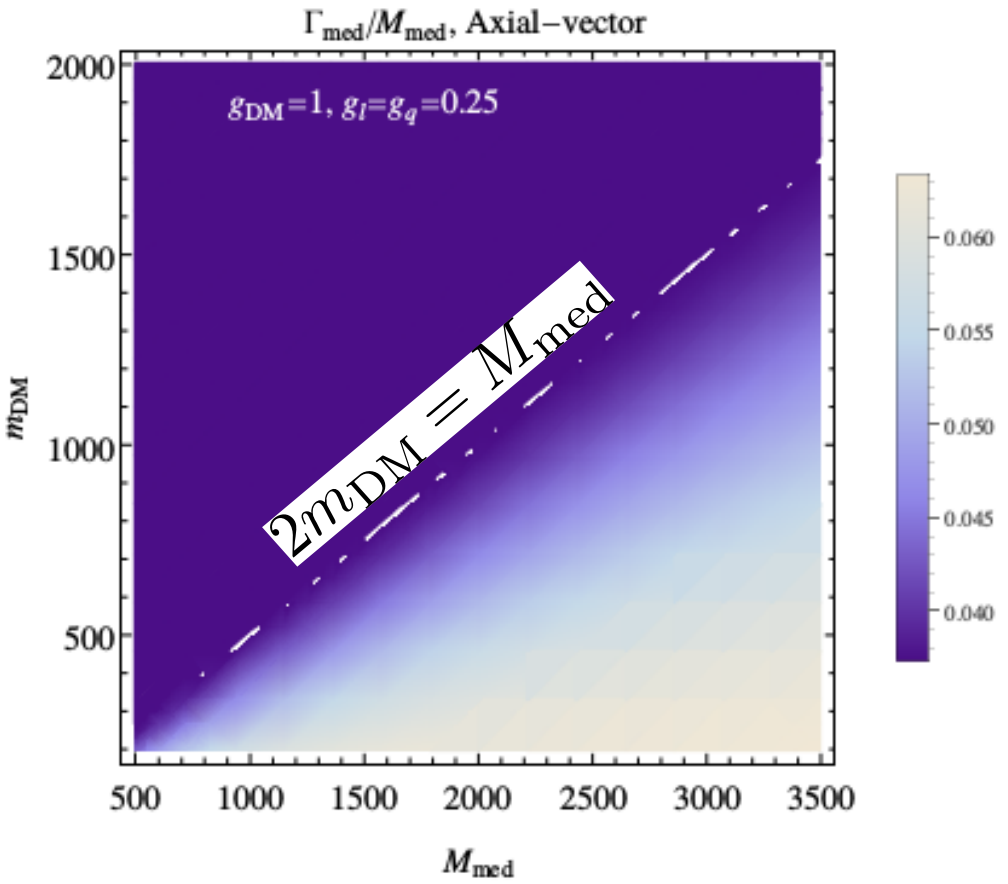
Take the following couplings: (standard choice for summary plots)

$$g_{\text{DM}} = 1, \quad g_\ell = g_q = 0.25$$

- For: $2m_{\text{DM}} < M_{\text{med}}$

  Width can easily be larger than 5% the mass (depending on couplings)

- Question is raised about how narrow the resonance can be in order to apply Resonant dilepton searches



For discussion

- For which relative width the existing dilepton resonant searches start loosing sensitivity?

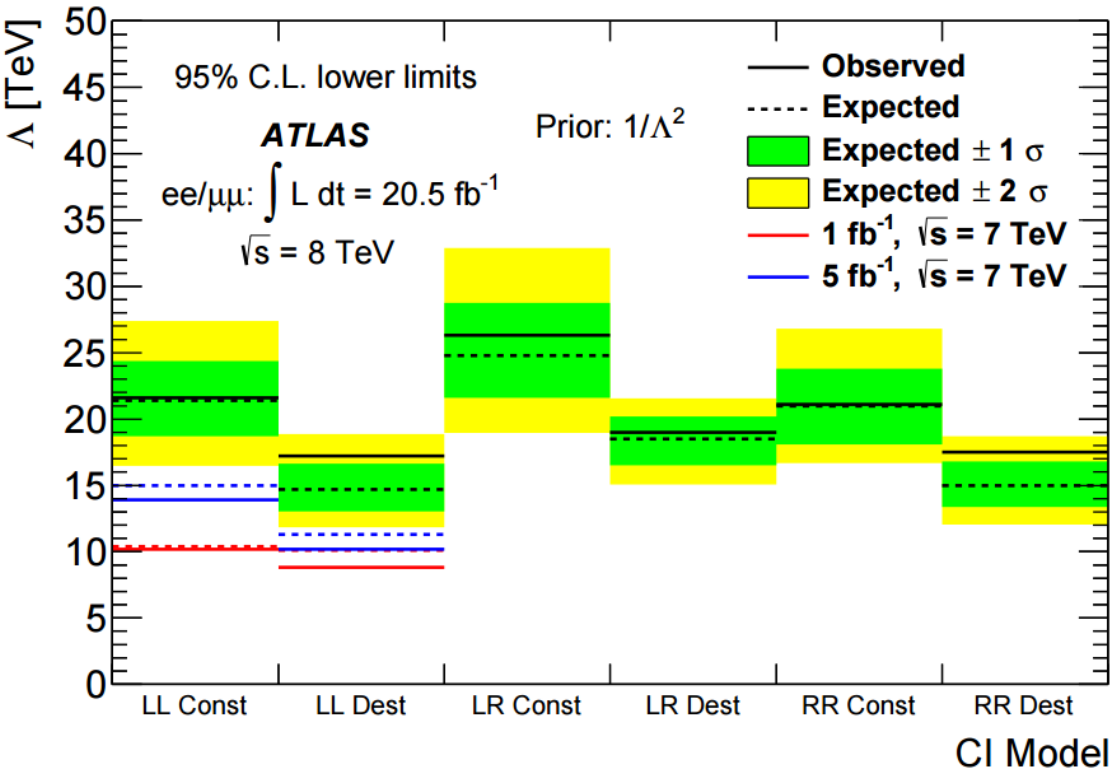
- Are there any experimental ideas to search for larger resonances?

- **To which extent searches for $(q\gamma_\mu\bar{q})(\ell\gamma^\mu\bar{\ell})$ contact interactions can be useful**

$$\mathscr{L} = \frac{g^2}{\Lambda^2}\,[\;\; \eta_{\mathrm{LL}}\,(\bar{q}_{\mathrm{L}}\gamma_\mu q_{\mathrm{L}})\,(\bar{\ell}_{\mathrm{L}}\gamma^\mu \ell_{\mathrm{L}}) + \eta_{\mathrm{RR}}\,(\bar{q}_{\mathrm{R}}\gamma_\mu q_{\mathrm{R}})\,(\bar{\ell}_{\mathrm{R}}\gamma^\mu \ell_{\mathrm{R}}) + \eta_{\mathrm{LR}}\,(\bar{q}_{\mathrm{L}}\gamma_\mu q_{\mathrm{L}})\,(\bar{\ell}_{\mathrm{R}}\gamma^\mu \ell_{\mathrm{R}}) + \eta_{\mathrm{RL}}\,(\bar{q}_{\mathrm{R}}\gamma_\mu q_{\mathrm{R}})\,(\bar{\ell}_{\mathrm{L}}\gamma^\mu \ell_{\mathrm{L}})\,]\,,$$

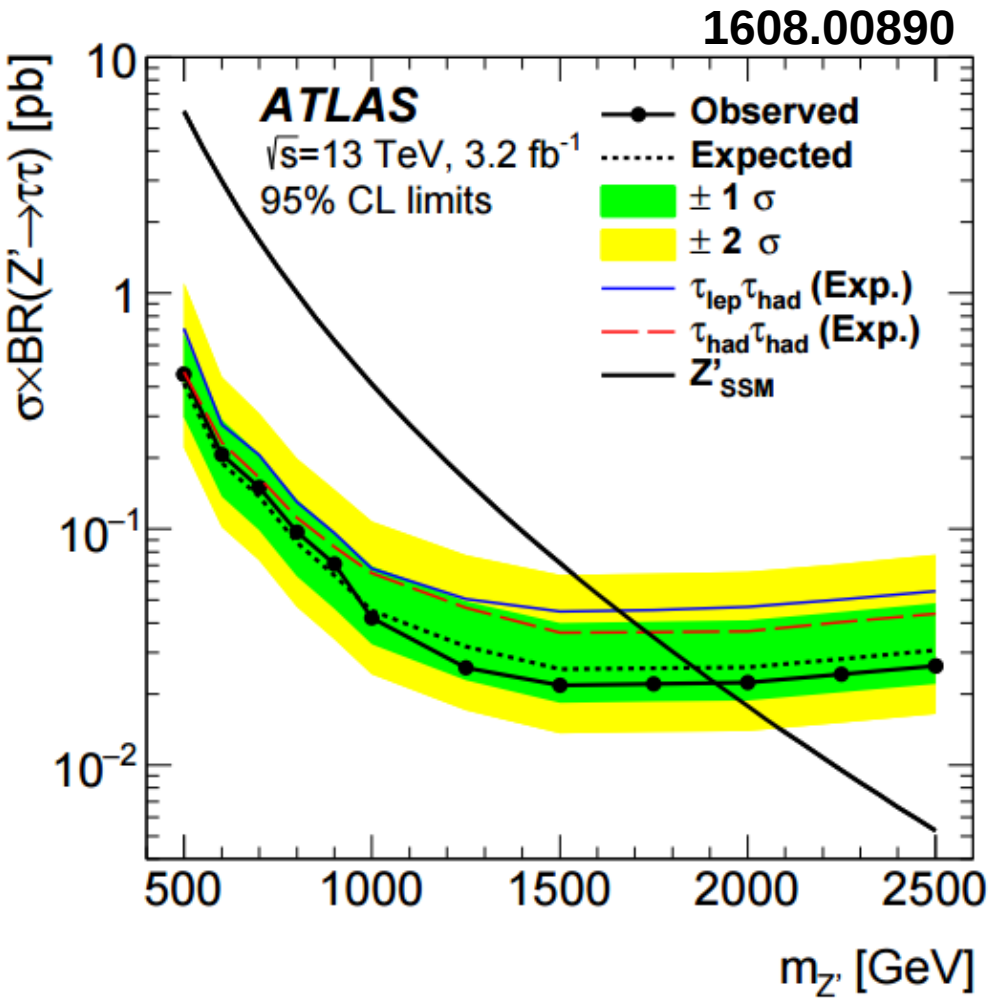
May translate into $\mathcal{O}(1\mathrm{TeV})$ limits for Z' mass and standard coupling values

1407.2410



For discussion

- What about $\tau^+\tau^-$ final state in resonant searches? Can those be used to constrain the models we are considering?



(a) Z'_{SSM} scenario