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Associated production of dark matter and Top quarks with the ATLAS detector

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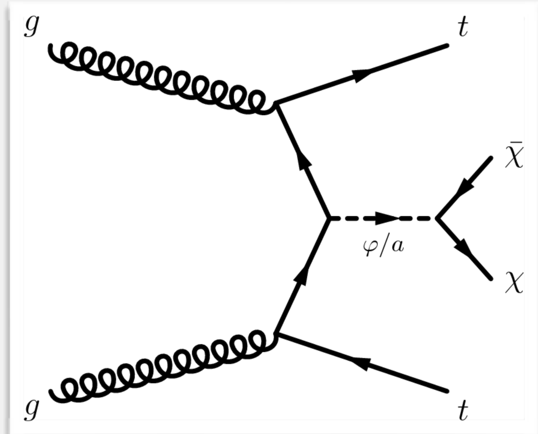
Introduction and Motivations

The three analyses focus on simplified model for DM production at the LHC through a spin 0 mediator between SM and DM:

- 4 theory parameters (m(χ), m(ϕ/α), g_q, g_χ). In the analyses $g_q = g_\chi = g$.
- Scalar or pseudo scalar mediators.



Models assume Yukawa-like couplings between DM and SM fermions, favouring the study of the process in heavy flavour quark final states.
In particular, in the analyses coupling to top quarks has been considered.
Depending on decay of top, analyses with final states including **zero**, **one** or **two** electrons or muons and **missing transverse momentum** have been performed.
Analyses are based on 13 TeV collisional data collected by ATLAS for a comprehensive luminosity of 13.3 fb^{-1}.

Event Selection

2 Lept.

- Dileptonic trigger (e/μ), requiring two electrons/muons or one of each.
- Two isolated leptons of opposite charge having 25 GeV (leading) and 20 GeV (subleading) p_t thresholds
- m_{ll} bigger than 20 GeV.

1 Lept.

- E_T^{miss} trigger, $E_T^{miss} > 200$ GeV,
- One isolated lepton having 25 GeV p_t thresholds and $m_T > 30$ GeV
- At least two jets, and $|\Delta\phi(\text{jet}, \boldsymbol{p_T^{miss}})| > 0.4$ for the first two jets
- $H_{T,sig}^{miss} > 5$

0 Lept.

- E_T^{miss} trigger, $E_T^{miss} > 250$ GeV,
- At least 4 jets, satisfying $p_T > 80, 80, 40, 40$ GeV respectively (1 b-tagged)
- $|\Delta\phi(\text{jet}, \boldsymbol{p_T^{miss}})| > 0.4$ for the first two jets
- $E_T^{miss,track} > 30$ GeV and $|\Delta\phi(\boldsymbol{p_T^{miss,track}}, \boldsymbol{p_T^{miss}})| < \pi/3$

Analysis Strategies

Two SRs have been defined to target low and high mediator masses for both 1 lept. and 2 lept. final states analyses, while only one SR for the 0 lept. analysis.
Optimisation performed using m(χ) = 1 GeV, g =3.5 and m(ϕ/α) = 10, 350 GeV (2 lept.), 100, 350 GeV (1 lept.), 350 GeV (0 lept.)

2 Lept.

Variable	DM-SRL	DM-SRH
$\|m_{\ell\ell} - m_Z\|$ [GeV] (SF only)	>20	>20
b-jet multiplicity	> 0	> 0
$\Delta\phi_{\rm boost}$	< 1.0	< 1.0
$m_{\rm T2}^{ll}$ [GeV]	>120	>120
$E_{\rm T}^{\rm miss}$ [GeV]	> 180	> 260

1Lept.

Variable	DM_low	DM_high
Number of (jets, b-tags)	$(\geq 4, \geq 1)$	$(\geq 4, \geq 1)$
Jet $p_{\rm T} >$ [GeV]	(60 60 40 25)	(50 50 50 25)
$E_{\rm T}^{\rm miss}$ [GeV]	> 300	> 330
$H_{\rm T,sig}^{\rm miss}$	> 14	> 9.5
$m_{\rm T}$ [GeV]	> 120	> 220
$am_{\rm T2}$ [GeV]	> 140	> 170
$\min(\Delta\phi(\vec{p}_{\rm T}^{\rm miss}, {\rm jet}_i))$ $(i \in \{1-4\})$	> 1.4	> 0.8
$\Delta\phi(\vec{p}_{\rm T}^{\rm miss}, \ell)$	> 0.8	–

0 Lept.

Variable	SRE
b-tagged jets	>1
$m^0_{{\rm jet},R=1.2}$	> 140 GeV
$m^1_{{\rm jet},R=1.2}$	> 60 GeV
$m^0_{{\rm jet},R=0.8}$	-
$m^1_{{\rm jet},R=0.8}$	-
$m_{\rm T}^{b,{\rm min}}$	> 200 GeV
$\tau-$veto	yes
$\Delta R(b,b)$	> 1.5
$E_{\rm T}^{\rm miss}$	> 300 GeV
$H_{\rm T}$	-
$E_{\rm T}^{\rm miss}/\sqrt{H_{\rm T}}$	$> 14\sqrt{GeV}$

$$H_T = \sum_{jets} p_{T_{jet}} \;; \qquad m_T^{b,min} = \sqrt{2p_T^b E_t^{miss}[1 - cos\Delta\phi(\boldsymbol{p_T^b p_T^{miss}})]}$$

$$\Delta\phi_{boost} = \text{azim. distance between } \boldsymbol{p_t^{miss}} \text{ and } \boldsymbol{p_{T Boost}^{ll}} = \boldsymbol{p_t^{miss}} + \boldsymbol{p_t^{l1}} + \boldsymbol{p_t^{l2}}$$

$$H_{T,sig}^{miss} = (H_{sig}^{miss} - 100GeV)/\sigma_{H_{sig}^{miss}} \;; \qquad H_{sig}^{miss} = \text{Neg. sum of jets and lept. } p_t$$

$$m_{T2}(\boldsymbol{P}_{T,1}, \boldsymbol{P}_{T,2}, \boldsymbol{q}_T) = \min_{\boldsymbol{q}_{T,1}+\boldsymbol{q}_{T,2}=\boldsymbol{q}_T}\{\max[m_T(\boldsymbol{q}_{T,1}, \boldsymbol{q}_{T,1}), m_T(\boldsymbol{q}_{T,2}, \boldsymbol{q}_{T,2})]\}$$

$$m_T = \sqrt{|\boldsymbol{p}_{T,1}||\boldsymbol{p}_{T,1}|(1 - cos(\Delta\phi))}$$

Background estimation

2 Lept. Background originated by top production events, mainly *ttbar* and *ttbar + Z*. Two CRs are defined according to lepton multiplicity and m^{ll}_{T2}, resulting in a very small signal contamination.

Selection	CRT	CRTZ
$m_{\rm T2}^{ll}$ [GeV]	60-100	>90
b-jet multiplicity	> 0	> 0
Jet multiplicity	> 1	> 1
Lepton multiplicity	2	> 2
$\Delta\phi_{\rm boost}$	< 1	–
$E_{\rm T}^{\rm miss}$ [GeV]	–	–

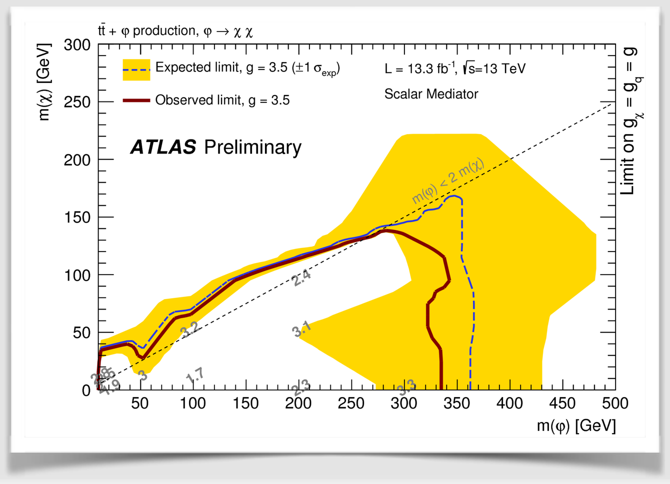
1 Lept. For each SR a dedicated CR has been defined for *ttbar, W+jets, single top, ttbar +W/Z*. Adopted general strategy is to invert the transverse mass requirement from a high threshold to a low one. Other requirements are loosened in order to increase statistical power.

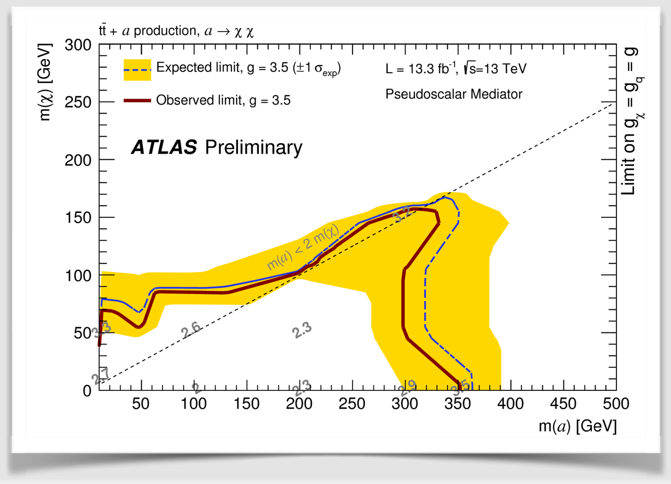
0 Lept. Main background processes are *Z-> νν + HF jets*, *ttbar* where W decays leptonically and leptons are misconstructed, *W-> lν + HF jets, single top, ttbar + Z -> νν*. CRs are defined by the presence of one or more leptons, to be orthogonal with respect to SRs. Angular distance between jets and E_T^{miss} and transverse mass between leptons and E_T^{miss} are optimised to reject SM multi jet processes.

Results

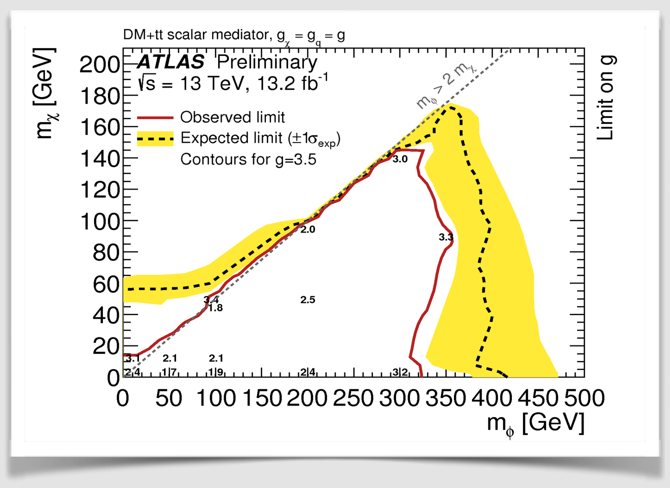
No significant excess has been found. Model independent upper limits have been set as well as limits on model with DM and top production for both scalar and pseudo scalar mediators. Numbers on the plots indicate the limits on the coupling.

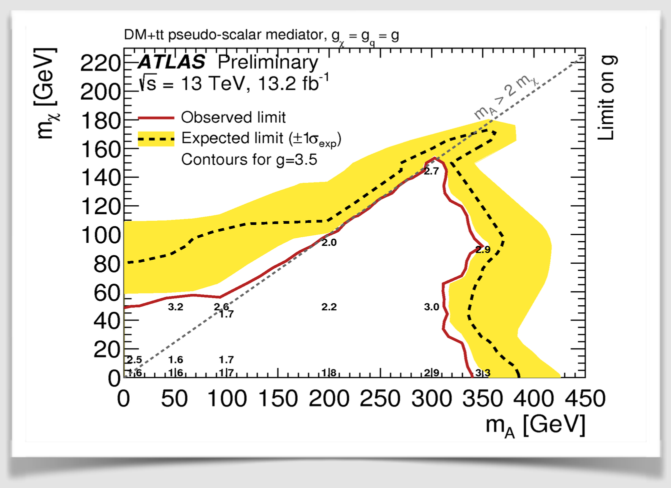
2 Lept.



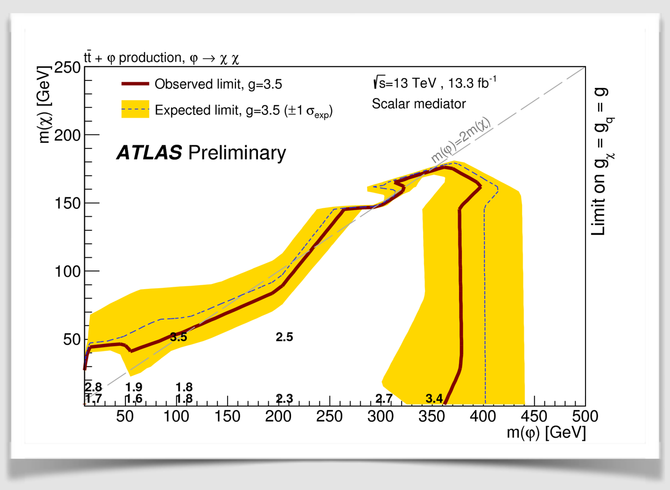


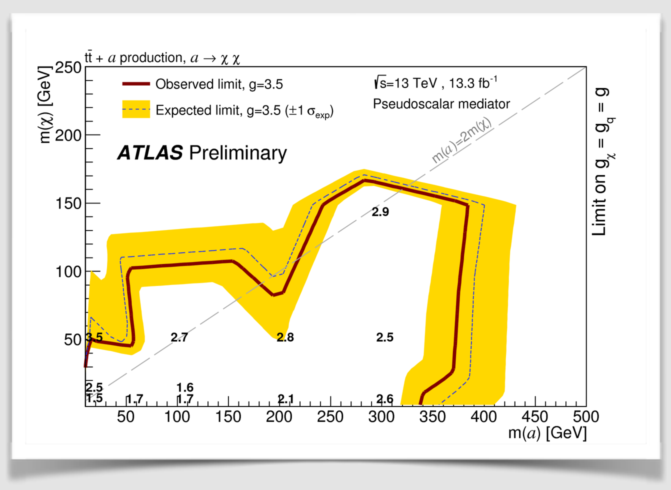
1 Lept.





0 Lept.



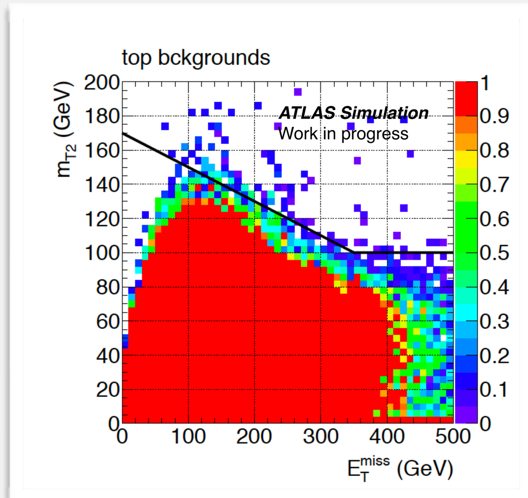


References

ATLAS-CONF-2016-050 (1 lept.)
ATLAS-CONF-2016-076 (2 lept.)
ATLAS-CONF-2016-077 (0 lept.)

Insight on SRs optimisation for 2 leptons final state analysis with full 2015 and 2016 datasets

Final state includes two leptons, two b-jets, and E_T^{miss}, with the leptons from the top quarks decay.
Background from *Z-jets* and diboson processes (reducible background), ttbar and *Wt* (same final state), *ttW* and *ttZ* processes (irreducible background).



The two main discriminating variable are E_T^{miss} and m_{T2}.
A correlation between the two variables has been found especially in the *ttbar* background.
A cut on a combination between E_T^{miss} and m_{T2} seems very promising to reject background.

$$c_{EM} = m_{T2} + 0.2E_T^{miss}$$