Search for Dark Matter
In events with heavy quarks And missing transverse energy With the ATLAS detector

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Abstract

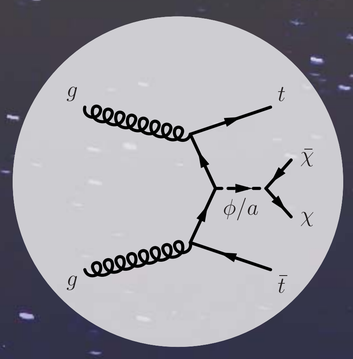
A wide search program is being carried at the LHC under the hypothesis that Dark Matter (DM) consists of Weakly Interacting Massive Particles (WIMPs). Final states with heavy flavour quarks and large momentum imbalance represent an interesting discovery signature which allows to probe models with scalar or pseudo-scalar interactions between the Standard Model (SM) and the dark sector under the assumption of Minimal Flavour Violation.

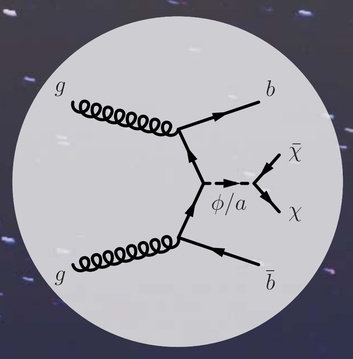
We present the most recent results of searches for DM produced in association with a pair of heavy flavour quarks (DM+HF) in ATLAS based on 36.1 fb-1 [1] and 13.3 fb-1 [2-4] of proton-proton collision data collected at a centre of mass energy of 13 TeV.

Previous ATLAS search at [5].

DM Models:

> Spin-0 mediator between the SM and the dark sector [6-8].
> Yukawa-like couplings to the SM fermions.
> Motivation to a search in association with Heavy Flavour quarks.
> Mediator is a (pseudo-) scalar.
> DM is a dirac fermion.





Representative diagrams at the lowest order for spin-0 mediator associated production with top and bottom quarks.

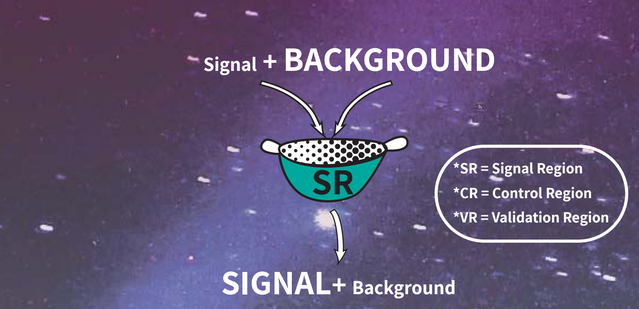
$$\mathcal{L}_{\phi}^{int} = -g_{\chi}\phi\bar{\chi}\chi - \sum_{fermions} g_q \frac{y_f}{\sqrt{2}}\phi\bar{f}f$$

$$\mathcal{L}_{a}^{int} = -ig_{\chi}a\bar{\chi}\gamma^5\chi - \sum_{fermions} ig_q \frac{y_f}{\sqrt{2}}a\bar{f}\gamma^5 f$$

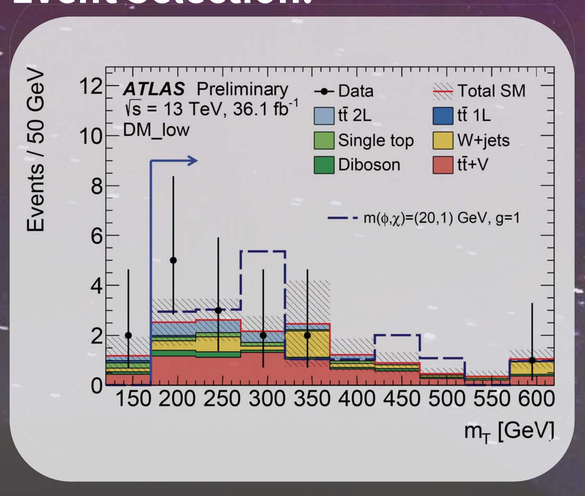
Lagrangian interaction terms for the analysis models.

Analysis Strategy:

> Using discriminating variables (between signal and SM background).
> SR* enriched with signal and low background.
> Estimate SM backgrounds normalization in dedicated CR.
> CR* similar to SR with minimal changes in order to:
>> Enrich targeted background.
>> Suppress signal contamination.
>> Achieve sufficient event yield.
>> Be orthogonal to other selections.
> Validate background estimation at dedicated VR*.
> Look at Data in SR.
> Interpretation of results - limits on the models.



Event Selection:



> 7 SRs, divided by the final signature in the detector.
> Differences in the kinematic distributions between the signal and the background were used for optimization.
> Each SR contains different dominant background processes.

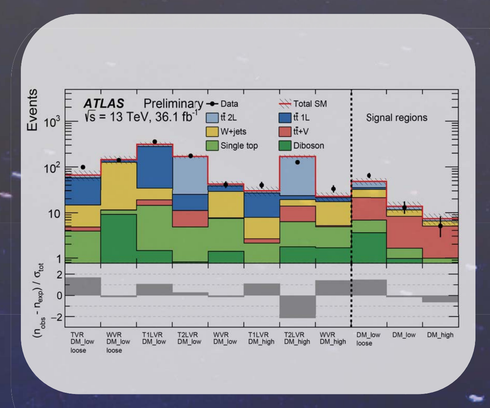
Transverse mass distribution in DM_low. The transverse mass is calculated between the lepton transverse momentum and the missing transverse momentum vector.

Channel	SR	Targeting	Main SM Background
$t\bar{t}+\chi\bar{\chi}$ (full hadronic)	SRE	Low & High mediator mass	$Z+jets, t\bar{t}+W/Z, t\bar{t}$
$t\bar{t}+\chi\bar{\chi}$ (semi − leptonic)	DM_low	Low mediator mass	$t\bar{t}+W/Z, W+jets, t\bar{t}$
	DM_low_loose	Low mediator mass	$t\bar{t}, t\bar{t}+W/Z, W+jets,$
	DM_high	High mediator mass	$t\bar{t}+W/Z, W+jets$
$t\bar{t}+\chi\bar{\chi}$ (di − leptonic)	DM-SRL	Low mediator mass	$t\bar{t}, t\bar{t}+Z$
	DM-SRH	High mediator mass	$t\bar{t}+Z$
$b\bar{b}+\chi\bar{\chi}$	SRb	Low mediator mass	$Z/\gamma+jets, t\bar{t}$

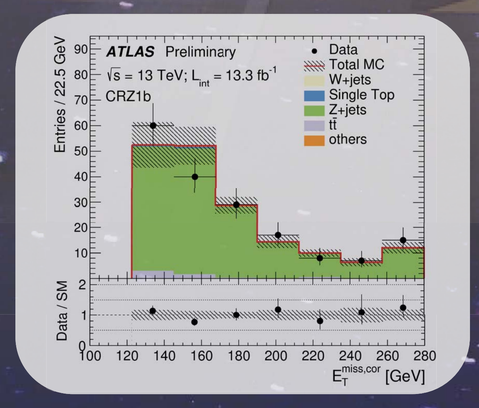
Background Estimation:

> Data driven estimation.
> Using similar variables to the SRs, stay orthogonal.
> Dedicated CRs in order to normalize:
>> Z (-> neutrinos) – using Z (-> charged leptons) for estimation.
>> Top-quark pair events – background mainly by hadronic taus and lost leptons.
>> Top-quark pair with a Z-boson events – irreducible background when Z (-> neutrinos).
>> W (-> jets), W (-> leptons) events.
>> Single top with a W-boson events.
> Normalizing the background at the SRs by the ratio between data and Monte Carlo simulation at the CRs.

> **Estimation is compatible with the Standard Model.**



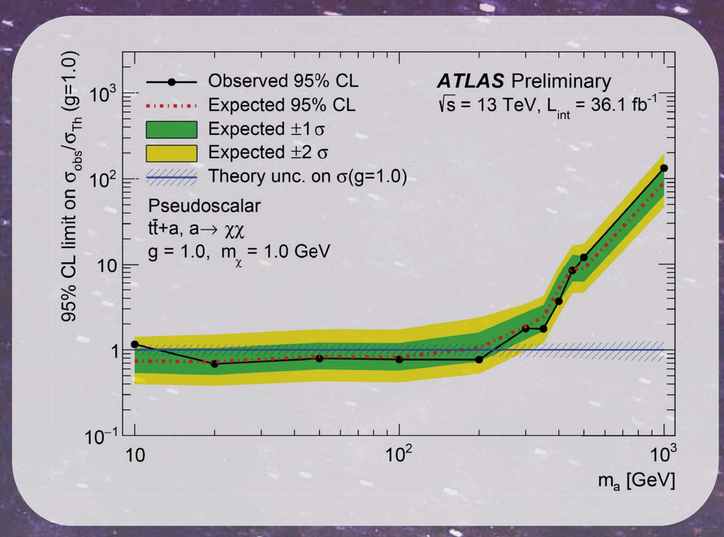
Comparison of the observed data with the predicted SM background in DM_low_loose, DM_low, and DM_high signal regions, and associated VRs.



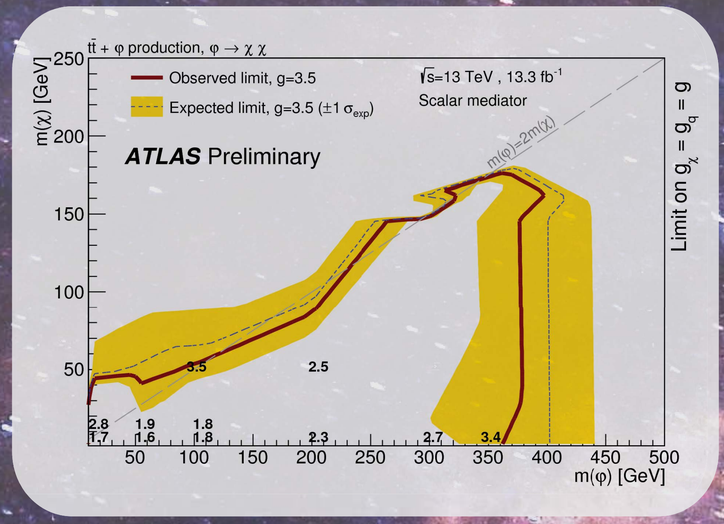
Vector sum of missing transverse momentum and two charged leptons transverse momentum distribution in CRZb1, used for estimation of events with a Z-boson decay to neutrinos.

Results:

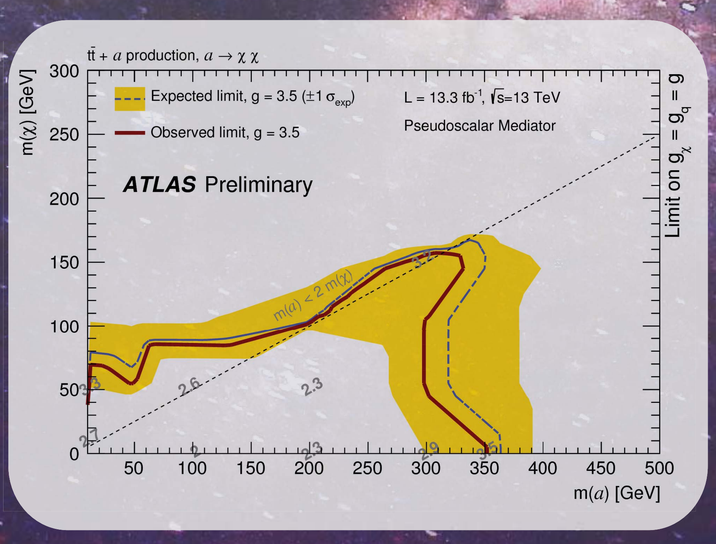
> **No significant excess over the Standard Model prediction.**
> Model independent limits on the visible beyond SM cross sections: **σ** x **A** x **ε**
>> **σ** is the production cross section for signal.
>> **A** is the detector acceptance.
>> **ε** is the selection efficiency.
> Set upper limits on the simplified models at 95% Confidence Level (CL).
> Cross sections: next-to-leading-order for semi-leptonic signature, leading-order for other signatures.



Exclusion limits for pseudo-scalar models as a function of the mediator mass for a DM mass of 1 GeV, using the semi-leptonic signature. The limits are calculated at 95% CL and expressed in terms of ratio of the excluded cross section over the nominal cross section for a coupling assumption of $g = g_\chi = g_q = 1$.



Exclusion limits for scalar models as a function of the mediator mass and the DM mass, using the full hadronic signature. The limits are calculated at 95% CL for a maximum coupling $g = g_\chi = g_q$ up to the perturbative limit of $g = 3.5$.



Exclusion limits for pseudo-scalar models as a function of the mediator mass and the DM mass, using the di-leptonic signature. The limits are calculated at 95% CL for a maximum coupling $g = g_\chi = g_q$ up to the perturbative limit of $g = 3.5$.

References:
1. ATLAS-CONF-2017-057
2. ATLAS-CONF-2016-077
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6. D. Abercrombie et al., arXiv:1507.00966 [hep-ex]
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