Search for Dark Matter in association with an energetic photon in proton-proton collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector

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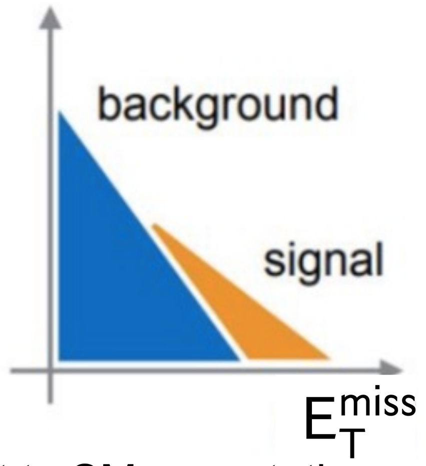
According to several astrophysical and cosmological evidences, Dark Matter (DM) accounts for about 27% of the Universe mass-energy, but its nature and properties are still largely unknown. Production at colliders is one of the possible strategies for DM detection, and it is being explored in a comprehensive effort within the ATLAS Collaboration at CERN. In this context, the Mono-γ analysis searches for an excess of events in final states with one energetic photon and missing transverse momentum in proton-proton collisions at the Large Hadron Collider (LHC). The full Run2 data collected in 2015-2018 by the ATLAS detector, at a centre-of-mass energy of 13 TeV and corresponding to a total integrated luminosity of 139 fb^{-1} is used, and the results are interpreted in terms of production of Weakly-Interacting Massive Particles (WIMPs) or Axion-Like Particles (ALPs).

Motivation

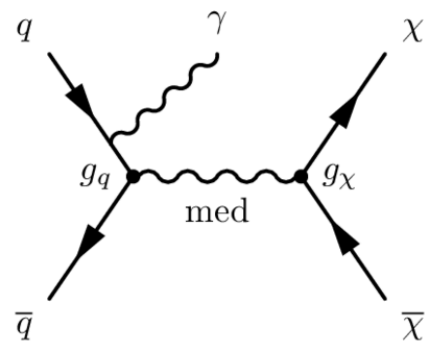
- DM production in proton-proton collisions at LHC is possible, if DM interacts with Standard Model (SM) particles.
- The production of DM particles, invisible to the detector, in association with a SM particle X (photon, W/Z, Higgs or jet) leads to a Mono-X signature: the visible particle recoils against undetected DM, thus producing an unbalance in the total transverse energy of the final state known as the missing transverse momentum (E_T^{miss}).
- An excess of events with high E_T^{miss} with respect to SM expectations can be interpreted in terms of DM production.



Signal models

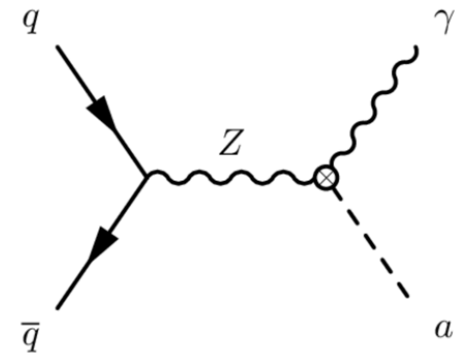
Two models of DM production have been considered:

WIMPs production
Simplified DM model of DM production in an s-channel with vector or axial-vector mediator



Free parameters:
- Mediator mass
- DM mass
- Mediator couplings to SM and DM sectors
- Decay width, fixed to minimal value

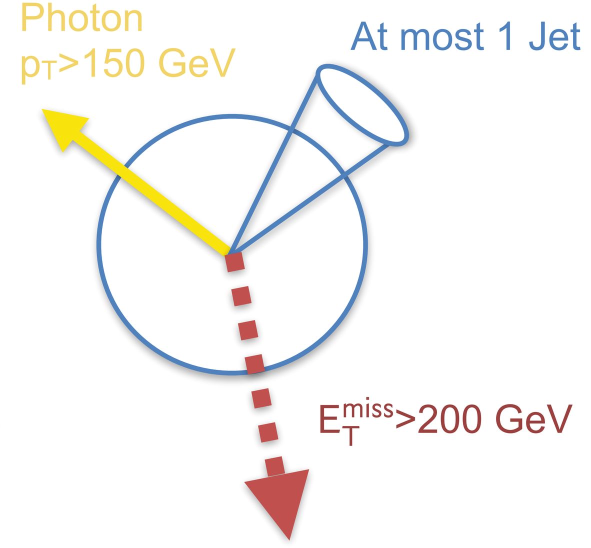
ALPs production
Effective Field Theory with scale f_a.
SM Lagrangian extended with a singlet scalar (ALP)



The assumption of null coupling to photons (motivated by experimental constraints), reduces the free parameters to:
- Theory scale, f_a
- Coupling $c_{\tilde{W}}$ to $\tilde{W}$ boson

Analysis selection

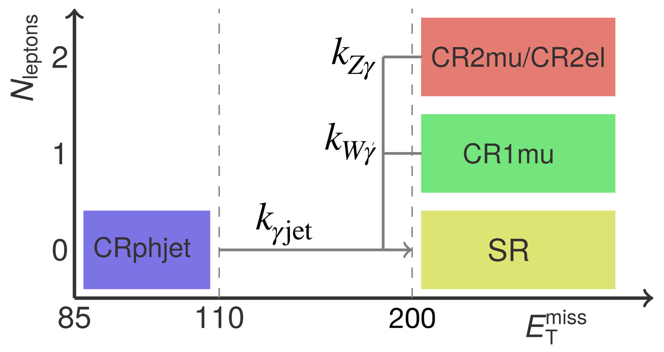
- Well reconstructed photon with p_T>150 GeV
- $|\Delta\phi(E_T^{miss},\gamma)| > 0.4$
- E_T^{miss} significance>8.5
- Veto on leptons
- At most 1 jet with p_T>30 GeV and $|\Delta\phi(E_T^{miss},\mathrm{jet})| > 0.4$
- 7 Signal Regions (SR) corresponding to different E_T^{miss} ranges:



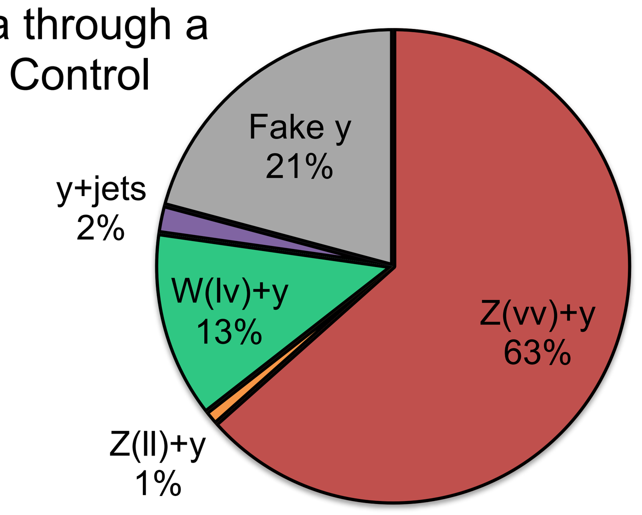
	SRI1	SRI2	SRI3	SRI4	SRE1	SRE2	SRE3
E_T^{miss} [GeV]	> 200	>250	>300	>375	200-250	250-300	300-375

Analysis strategy and results

Real photon backgrounds: MC expectations are normalized to data through a background-only likelihood fit performed simultaneously in dedicated Control Regions (CRs), each enriched with a specific background.



- $Z(\nu\nu)+\gamma$, $Z(ll)+\gamma$ } 2-lepton CR
- $W(l\nu)+\gamma$: 1-muon CR
- γ + jets : γ+jet CR

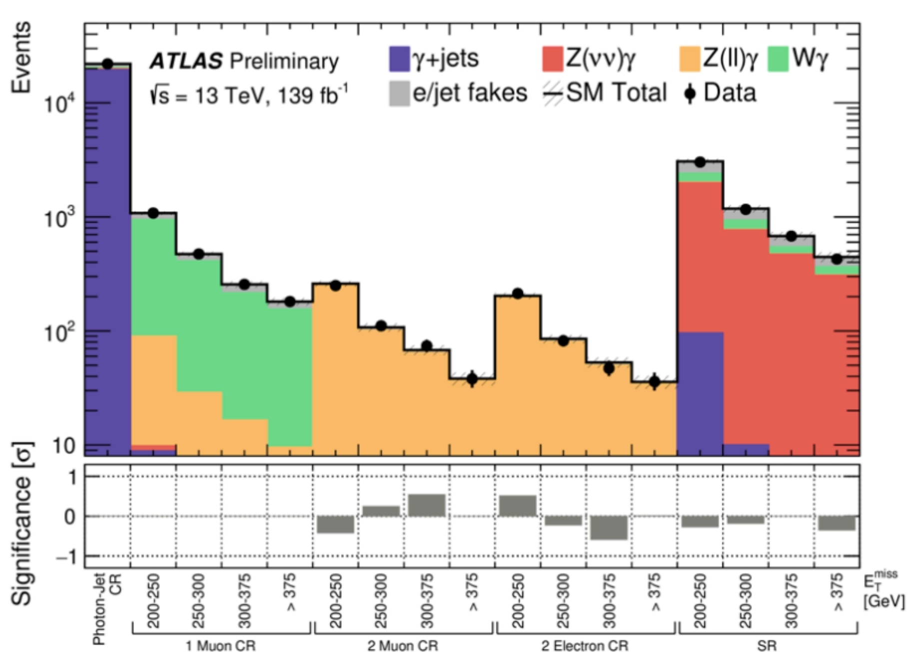


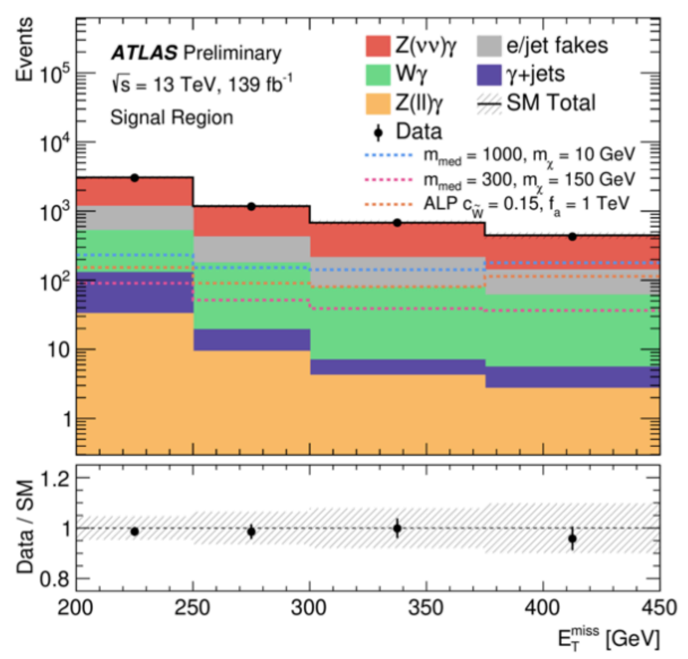
Fake Photons backgrounds: due to jets or electrons misidentified as photons, mainly in W/Z + jets

Electrons faking photons: electron control samples normalized through fake rate from $Z(ee)+\gamma$

Jets faking photons: 2 dimensional side-band method

Agreement between data and SM expectations, after background-only multi-bin fit (in SRE1, SRE2, SRE3, SRI4). Experimental and theoretical systematic uncertainties included as nuisance parameters of the likelihood function.





No excess observed within uncertainties => set 95% CL limits

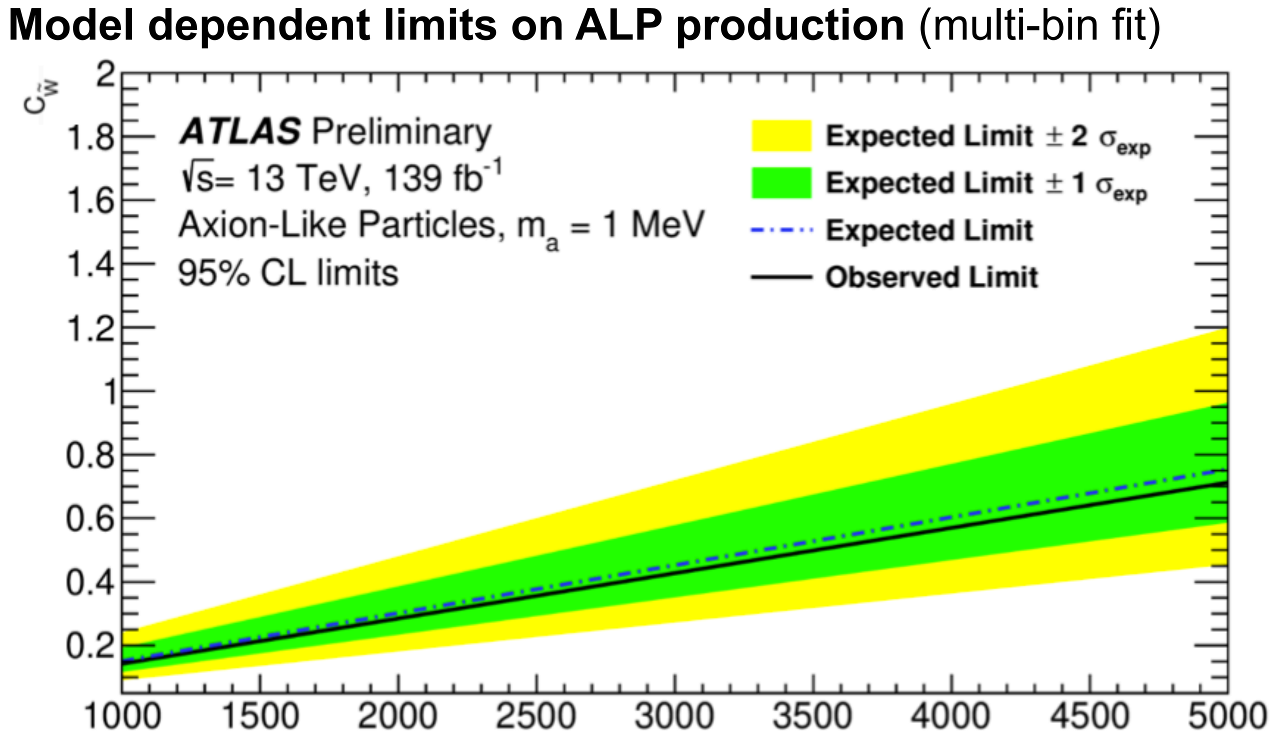
Interpretation of results

A simultaneous likelihood fit, including a signal component, is performed separately in each SR (single-bin fit) or in all SRs (multi-bin fit) and associated CRs.

Model independent limits on the visible cross-section of new physics (single-bin fit)

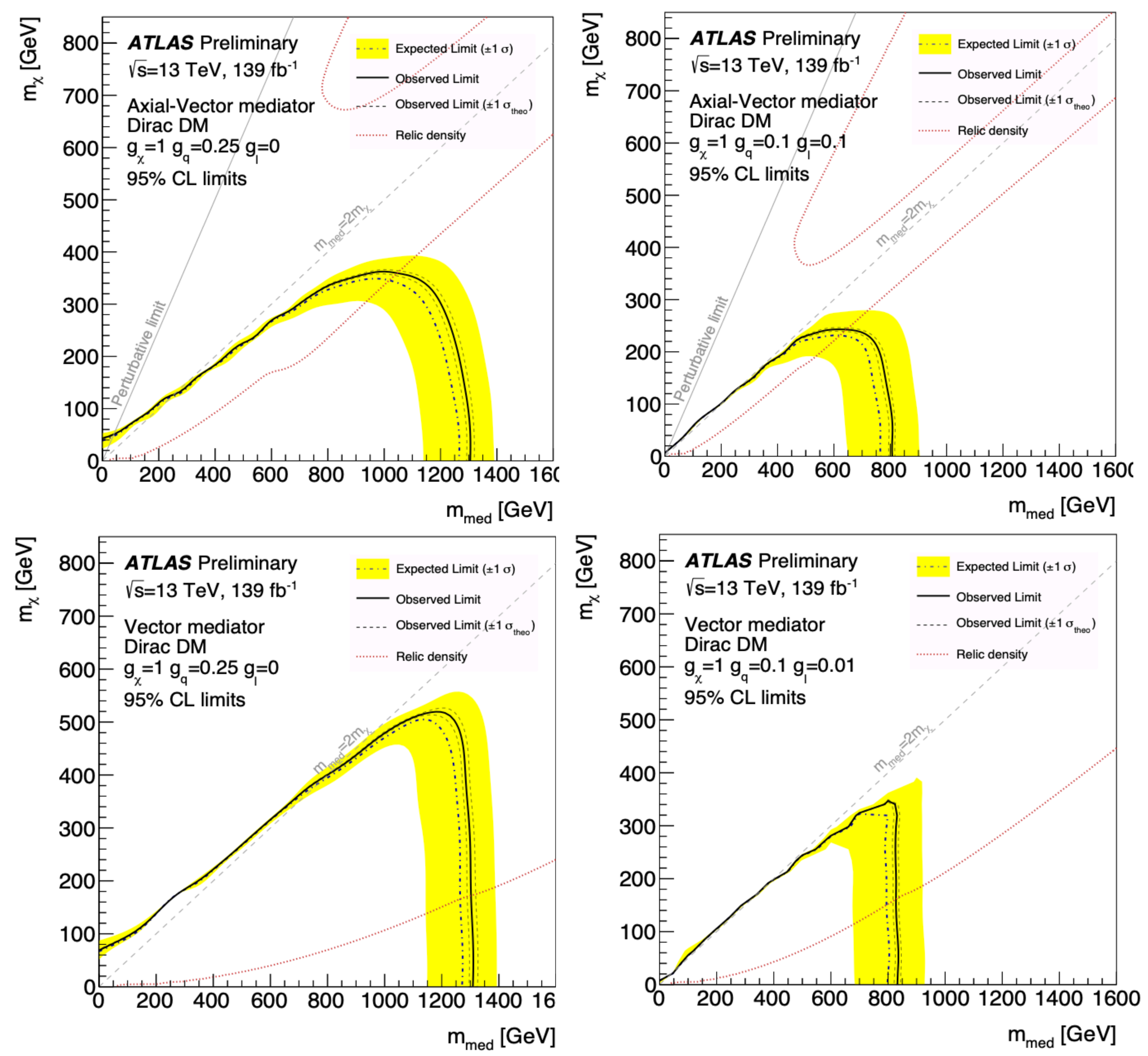
Signal region	$(\sigma\times A\times\epsilon)^{95}_{obs}$ [fb]	$(\sigma\times A\times\epsilon)^{95}_{exp}$[fb]	N^{95}_{obs}	ϵ [%]
SRI1	2.54	$2.79^{+1.06}_{-0.77}$	353	76
SRI2	1.48	$1.67^{+0.63}_{-0.46}$	205	74
SRI3	0.96	$1.07^{+0.40}_{-0.29}$	133	72
SRI4	0.57	$0.65^{+0.26}_{-0.18}$	80	67
SRE1	2.18	$2.17^{+0.87}_{-0.60}$	304	75
SRE2	1.07	$1.15^{+0.43}_{-0.31}$	149	75
SRE3	0.80	$0.81^{+0.30}_{-0.22}$	112	71

Model dependent limits on ALP production (multi-bin fit)



$c_{\tilde{W}}/f_a > 1.4\times10^{-4}$ GeV^{-1} excluded at 95% CL.

Model dependent limits on WIMP production (multi-bin fit)
Fixed couplings: g_χ=1, g_q=0.25, g_l=0 for Axial-Vector and Vector mediators or g_χ=1, g_q=0.1, g_l=0.1 (0.01) for Axial-Vector (Vector) mediator



The area below the curves is excluded at 95% CL.

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