Resonant Searches for Dark Matter Mediators at ATLAS

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On Behalf of the ATLAS Collaboration

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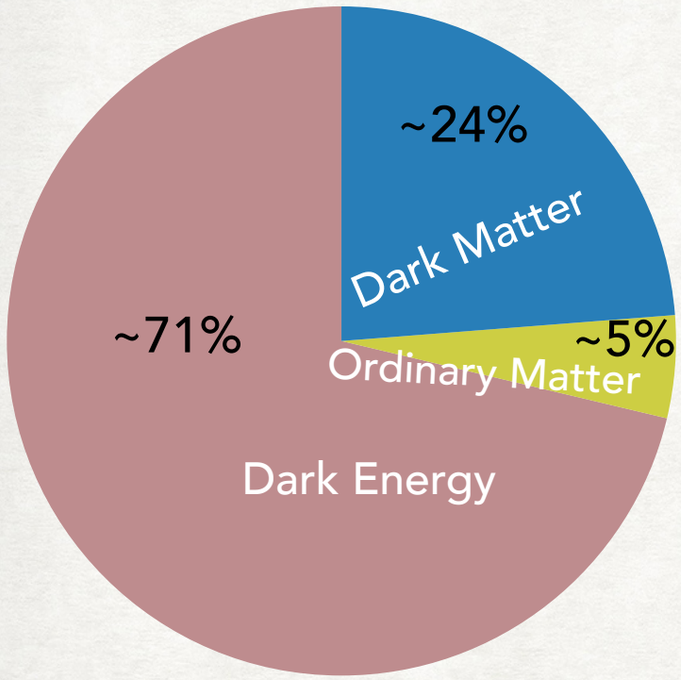
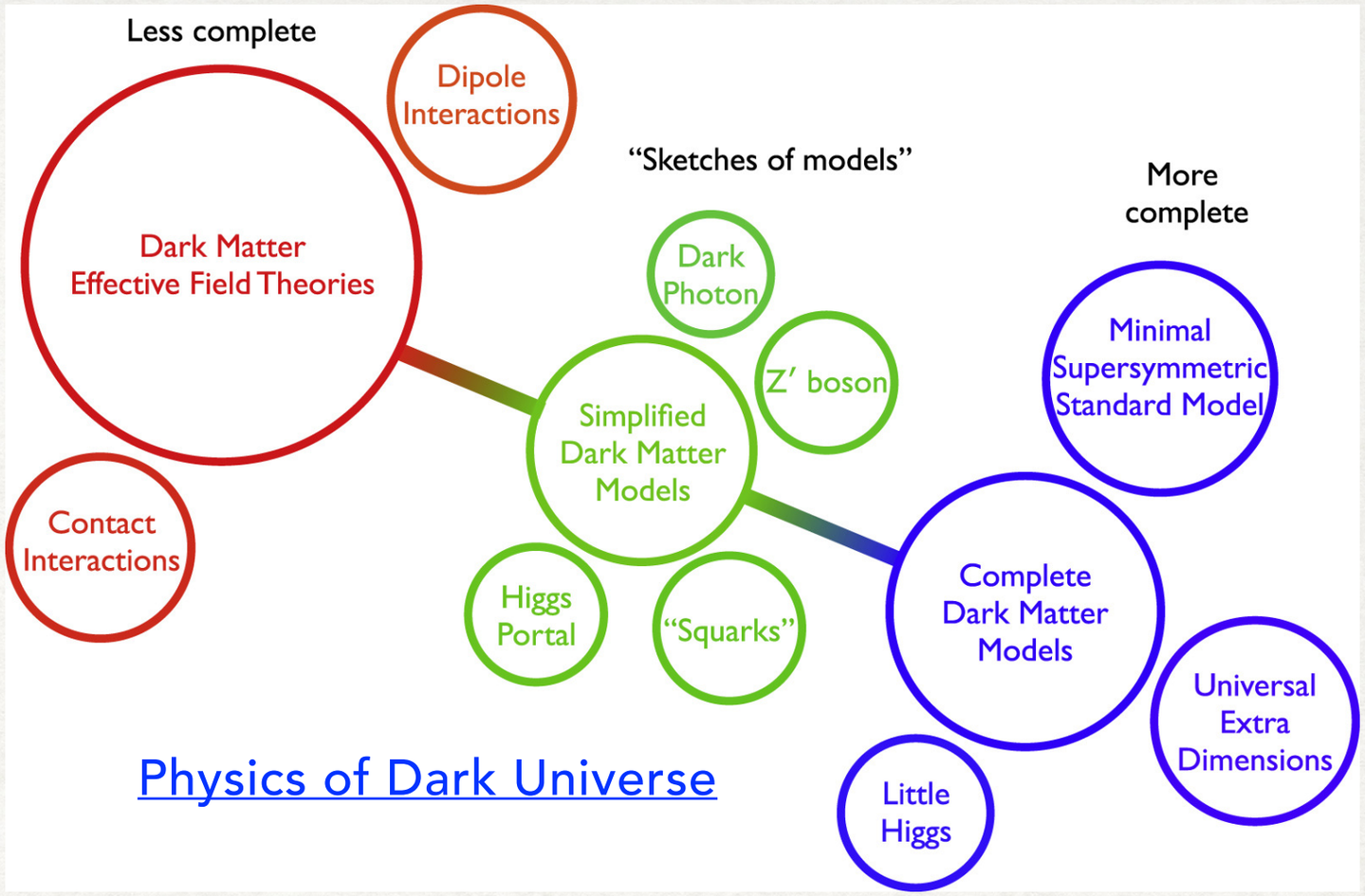
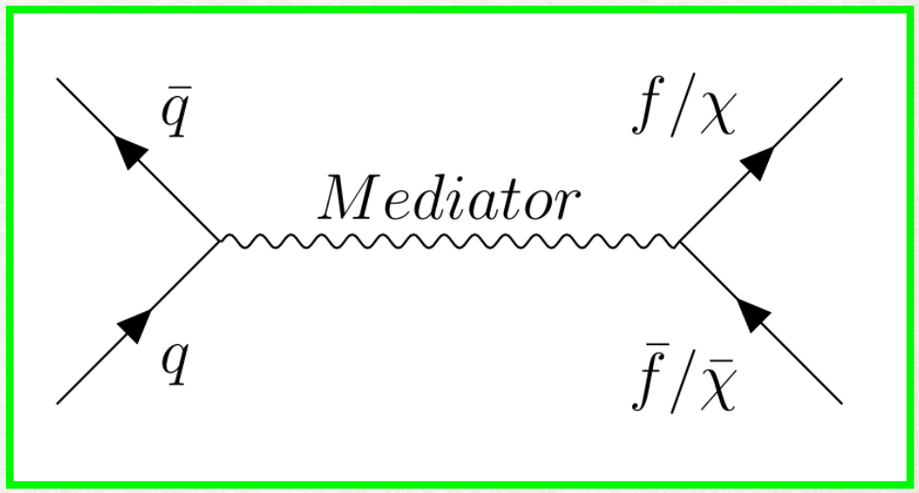
Introducing Dark Matter





- What do we know about DM?
  - Gravitationally interacting stable particle.
- This presentation focuses on the resonance searches for mediator particles facilitating interactions between DM and SM particles with ATLAS.
  - Mono-top CERN-EP-2022-040
  - Dark meson ATL-COM-PHYS-2024-209
  - 2HDM+a combination CERN-EP-2023-088
  - Dark photon ANA-EXOT-2023-01
  - Dark Higgs Boson ATLAS-COM-CONF-2024-007



Mono Top

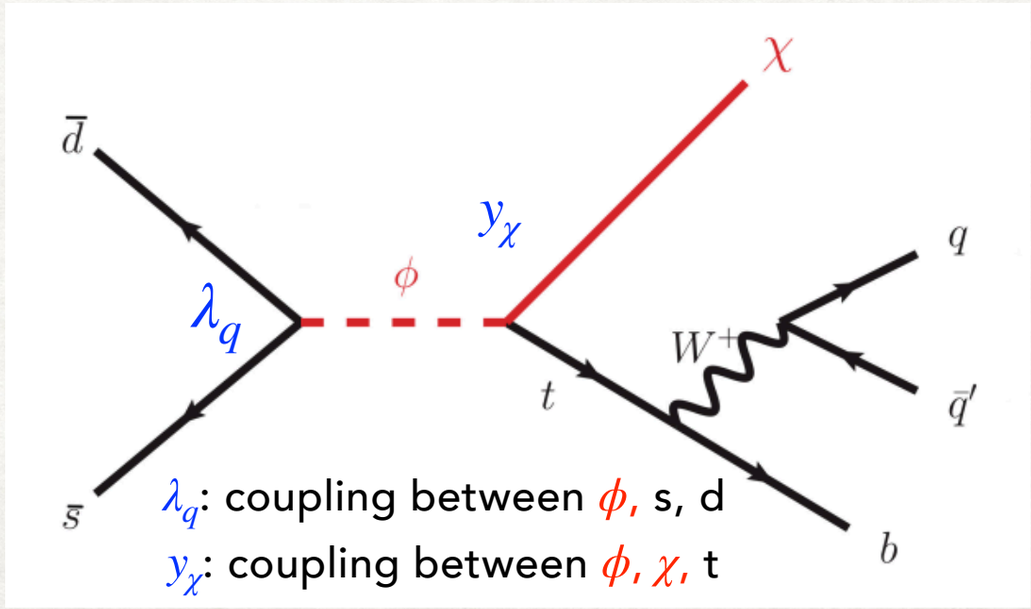
CERN-EP-2022-040

Search for invisible particles produced in association with single top quarks in proton–proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

The ATLAS Collaboration

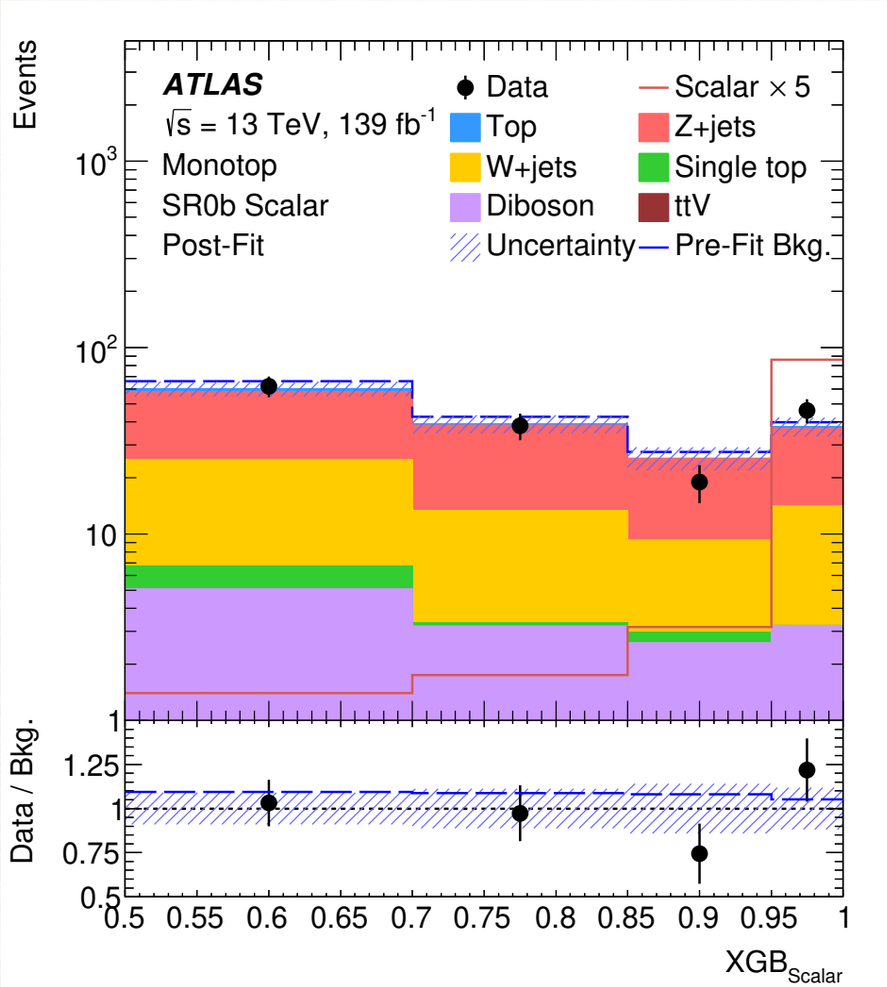
Analysis Overview

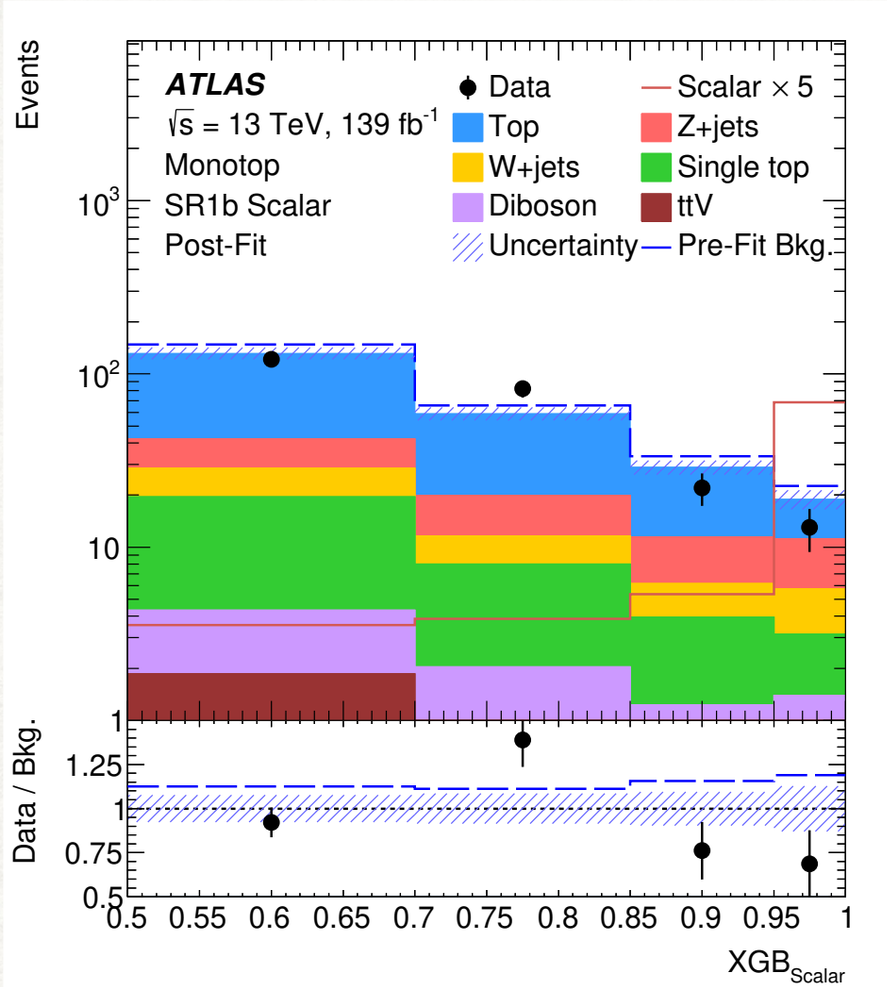
- Search for a DM mediator particle produced in association with a hadronically decaying single top-quark using the full Run 2 ATLAS dataset: *mono-top* signature (jet + E_T^{miss}).
- Benchmark model studied:
  - DM (χ) production in association with top quark with a scalar mediator ϕ (arxiv:1109.5963).
- Analysis strategy:
  - Scalar DM samples: $m_\phi \in [2500, 6000]$ GeV, $m_\chi \in [500, 5500]$ GeV, $\lambda_q \in [0.2, 1]$ and $y_\chi \in [0.2, 0.6]$.
  - E_T^{miss} trigger with E_T^{miss} > 250 GeV.
  - Major SM backgrounds: $t\bar{t}$ and V+ jets.
  - Gradient boosted decision tree discriminant scores in combination with the b-jet multiplicity are used to define SRs: SR0b and SR1b.
  - Dedicated CRs and VRs are defined for background estimations.



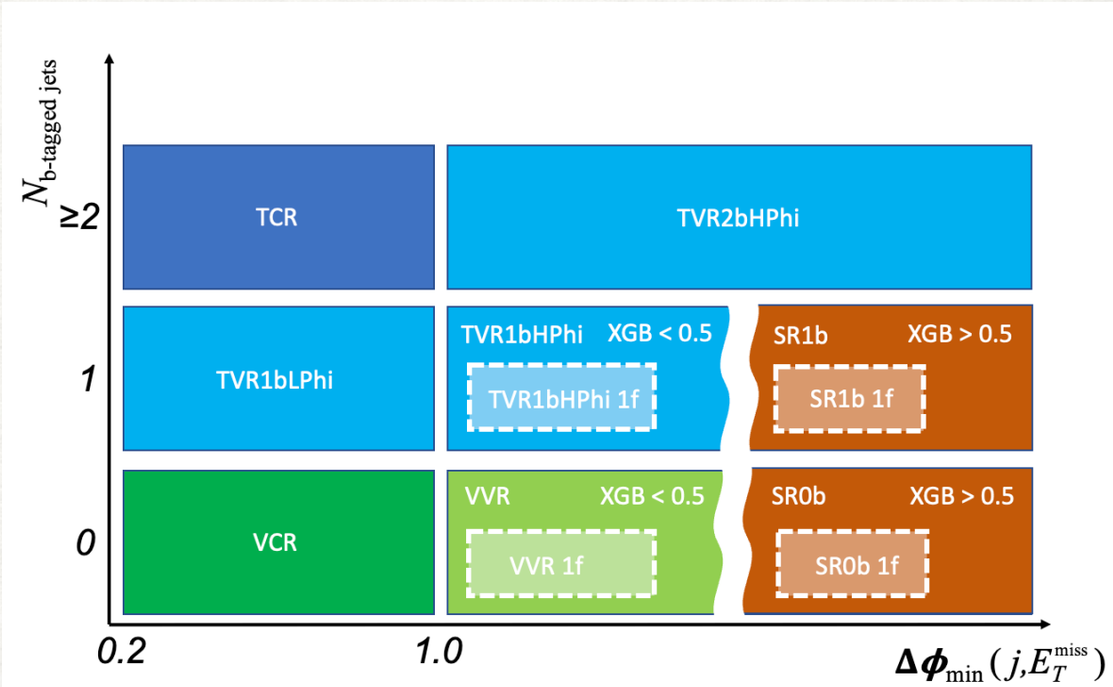
Results

CERN-EP-2022-040

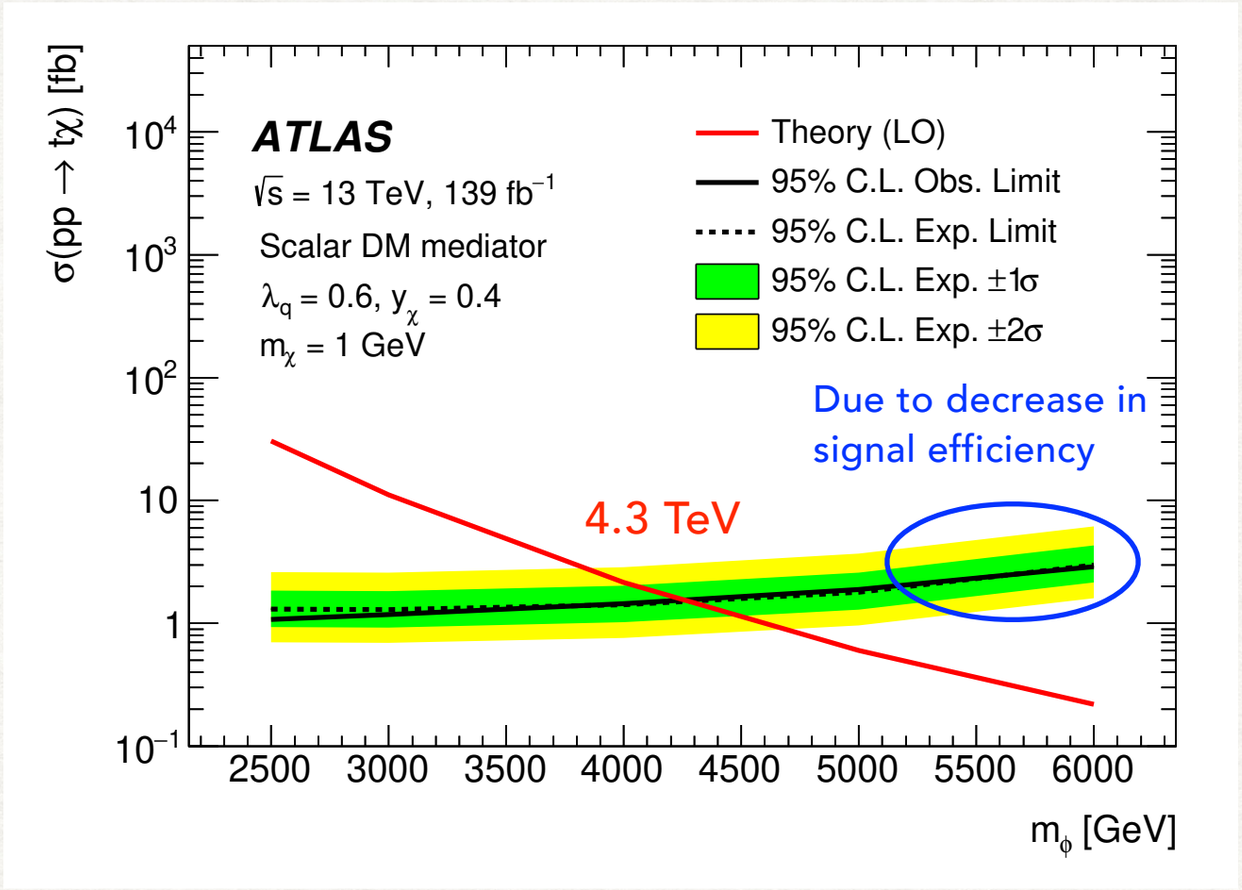


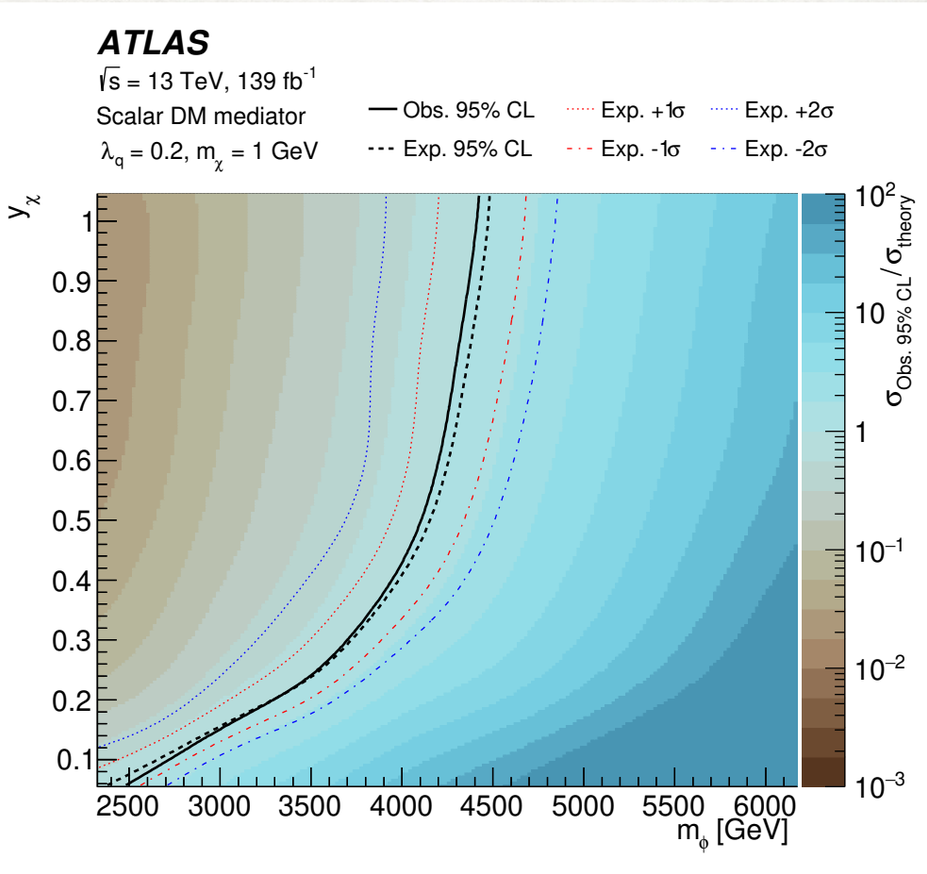


- A profile-likelihood fit is performed with XGBoost score distribution (trained with m_ϕ = 4 TeV) as the discriminant.
- No significant excess is observed: 95% CL upper limits on DM signal cross-section are derived as a function of model parameters.

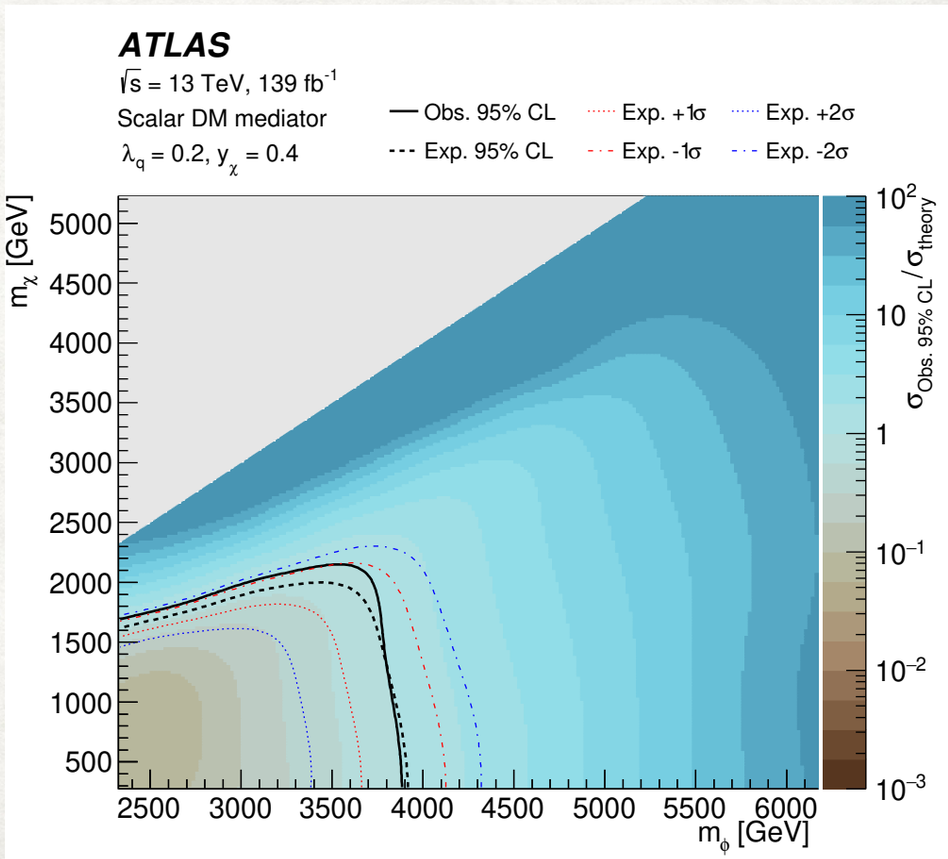


Results





- Exclusions:
  - For λ_q = 0.6, y_χ = 0.4 and m_χ = 1 GeV, $m_\phi < 4.3$ TeV is excluded: improves the previous results (JHEP 05 (2019) 41) by 800 GeV.
  - All values of λ_q are excluded for m_ϕ < 3.4 TeV.
  - All values of y_χ are excluded for m_ϕ < 2.5 TeV.
- Due to the E_T^{miss} trigger and boosted top requirement, the analysis is mainly sensitive to $(m_\phi - m_\chi)$ > 500 GeV regions.



Dark Meson

ATL-COM-PHYS-2024-209

Search for dark mesons decaying to top and bottom quarks with the ATLAS detector in 140 fb^{-1} of proton–proton collisions at $\sqrt{s} = 13$ TeV

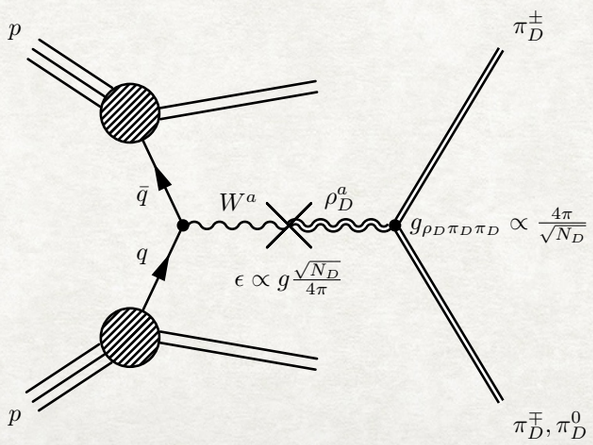
The ATLAS Collaboration

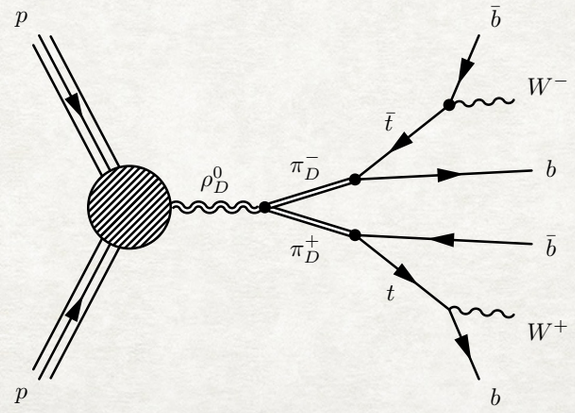
Analysis Overview

- Search for dark mesons decaying to top and bottom quarks is performed using the full Run 2 ATLAS dataset.
- Benchmark model studied:
  - Strongly-coupled dark matter model ($SU(2)$): Stealth Dark Matter (arxiv:1503.04203).
  - Manifests DM candidates in the form of composite dark mesons: triplet of dark pions π_D dark rhos ρ_D.
- Analysis strategy:
  - Analysis scans $\eta < 0.5$ where $\eta = m_{\pi_D}/m_{\rho_D}$ to ensure only on-shell production of π_D .
  - Final state: Gaugephobic decay of $\pi_D^{\pm}$, $\pi_D^{\pm}/\pi_D^0 \to ttt + b$ or $tt + bb$: all-hadronic and 1-lepton channel.

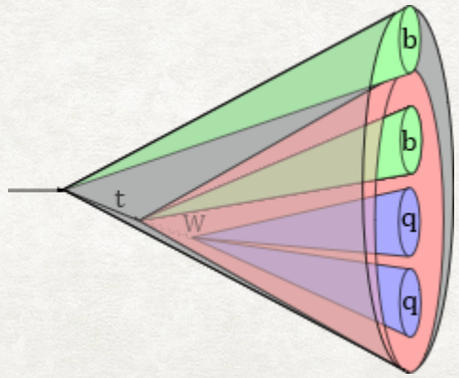
- All hadronic channel:
  - SRs are categorized in 9 bins based on the leading and sub-leading large-R jet masses.
  - Trigger: H_T ($\sum_{jets} E_T$ within $|\eta| < 2.8$) trigger used with H_T > 1150 GeV.
  - Major SM background: multijet
  - A profile-likelihood fit is performed using the yields.

- 1-lepton channel:
  - SRs are defined using $m_{bb_{\Delta R_{min}}}$ and $\Delta R(l, b_2)$.
  - Trigger: single-lepton
  - Major SM background: $t\bar{t}$ and $t\bar{t}$+HF.
  - A profile-likelihood fit is performed using $m_{J_{had}} + m_{J_{lep}}$ distribution.





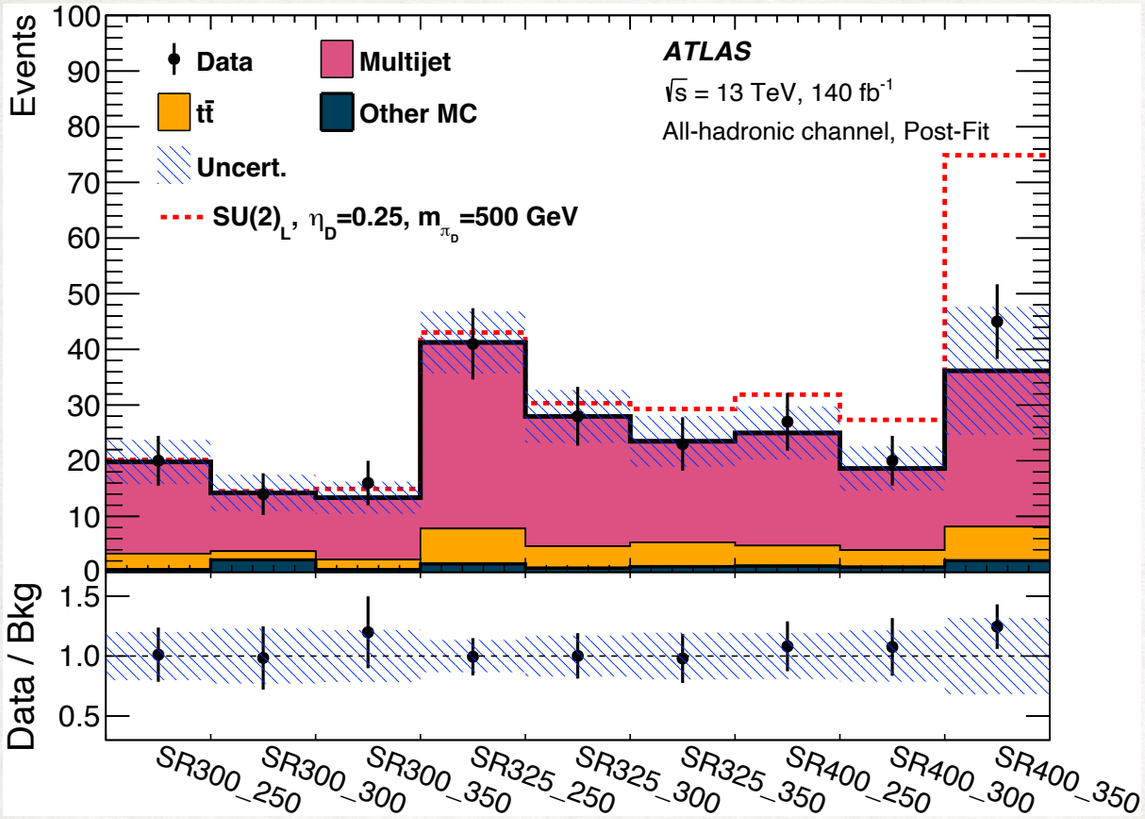
Federica Piazza's Poster

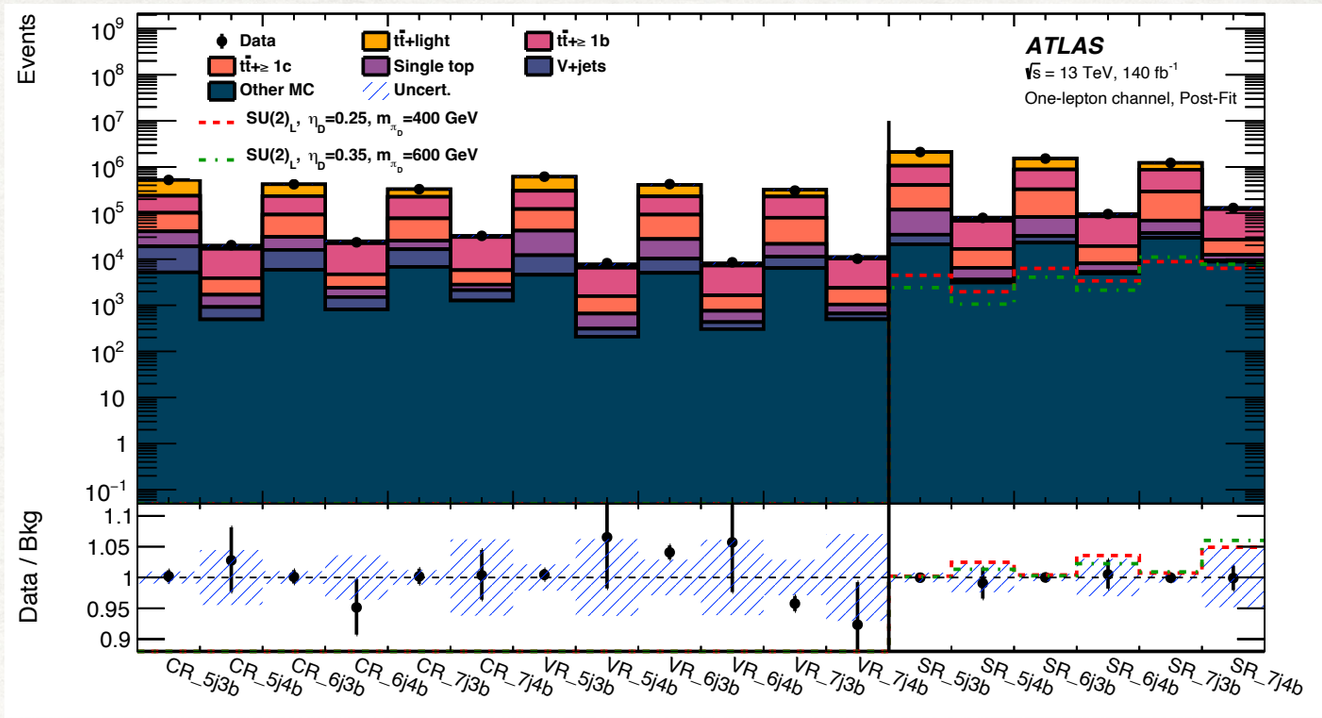


Large-R jets (R=1.2)

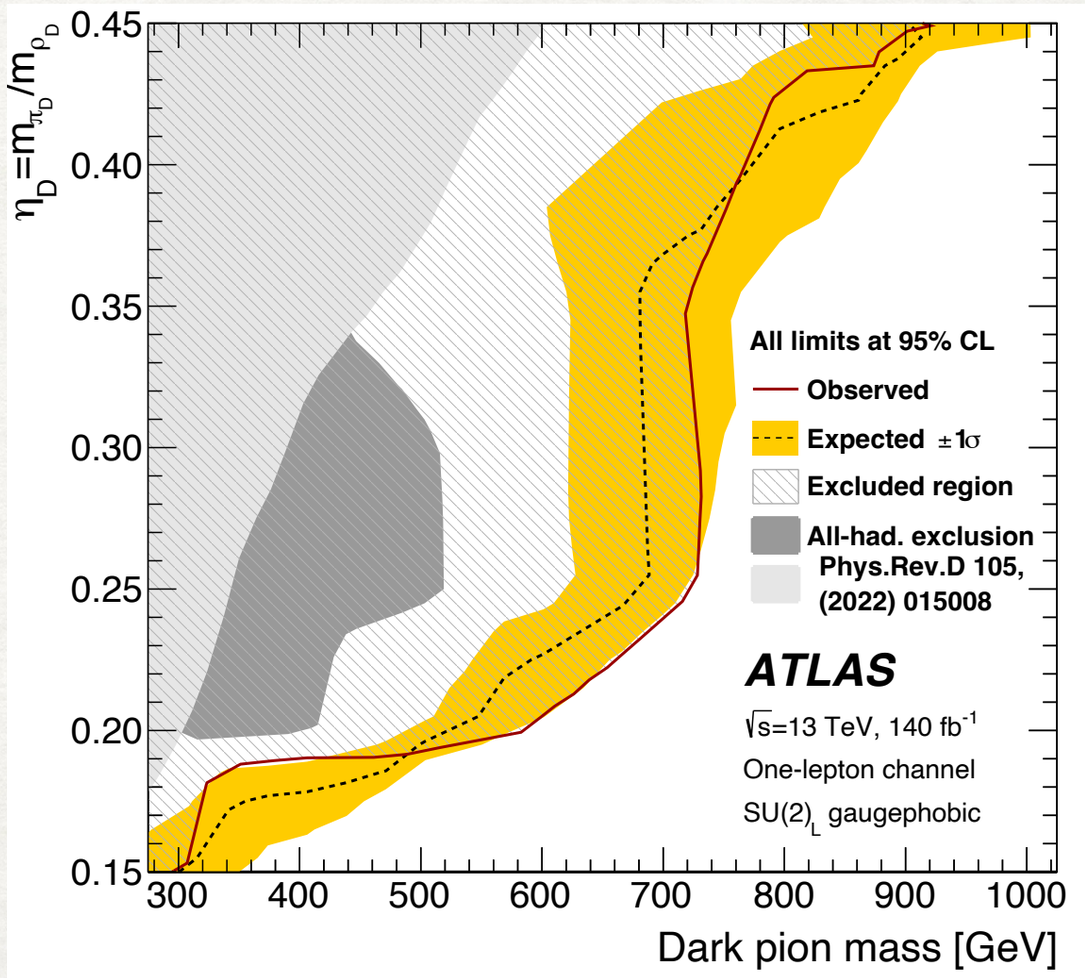
Results

ATL-COM-PHYS-2024-209





- No significant excess is observed: strongest 95% CL exclusion limits in the η-$m_{\pi D}$ plane from the 1-lepton channel.
- Exclusion limits:
  - Exclusion is down to η = 0.20 and $m_{\pi D}$ < 550 GeV in the all-hadronic channel due to boosted topology and lower cross-sections.
  - For η = 0.45, $m_{\pi D}$ < 940 GeV are excluded in the 1-lepton channel.
  - For η = 0.25, $m_{\pi D}$ < 740 GeV are excluded in the 1-lepton channel.



2HDM+a Summary

CERN-EP-2023-088

Combination and summary of ATLAS dark matter searches interpreted in a 2HDM with a pseudo-scalar mediator using 139 fb^{-1} of $\sqrt{s} = 13$ TeV pp collision data

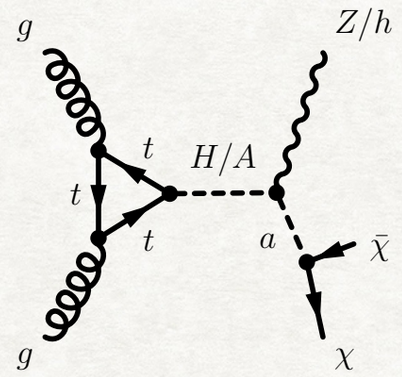
The ATLAS Collaboration

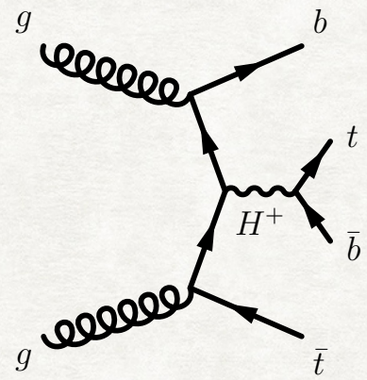
Analysis Overview

- A combination of DM searches using the full Run 2 ATLAS dataset: aims to constrain the Type-II $2HDM + a$ (arxiv:1701.07427) parameter space: $m_a - m_A$, $m_{A/a} - \tan\beta$, $m_a - m_\chi$, $sin\theta$, m_χ.
- β is the ratio of v.e.v between the 2 Higgs doublets, θ is the mixing angle between a and A.
- The most constraining signatures covering complementary $2HDM + a$ parameter space are statistically combined.

  - $E_T^{\text{miss}} + h(b\bar{b})$ JHEP 11 (2021) 209
    - E_T^{miss} trigger and $E_T^{\text{miss}} > 150$ GeV
    - Fit discriminant: m_{bb}
  - $E_T^{\text{miss}} + Z(ll)$ Phys. Lett. B 829 (2022) 137066
    - Single-lepton triggers
    - Fit discriminant: ZZ transverse mass
  - $tbH^{\pm}(tb)$ JHEP 06 (2021) 145
    - $m_{H^\pm} \in [200, 2000]$ GeV with narrow-width approximation only
    - Single-lepton triggers
    - Fit discriminant: A NN output score

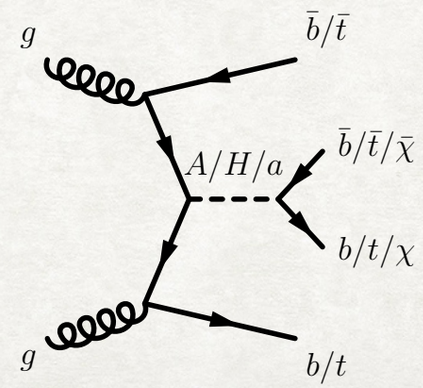
Statistically combined





- Orthogonality is maintained before combining the analyses using b jet and lepton multiplicity.
- Systematics treatments:
  - Correlated: NPs related to object reconstructions (lumi, pile-up, leptons, MET, JER).
  - Uncorrelated: b-tagging NPs and NPs which are moderately constrained in individual analyses.

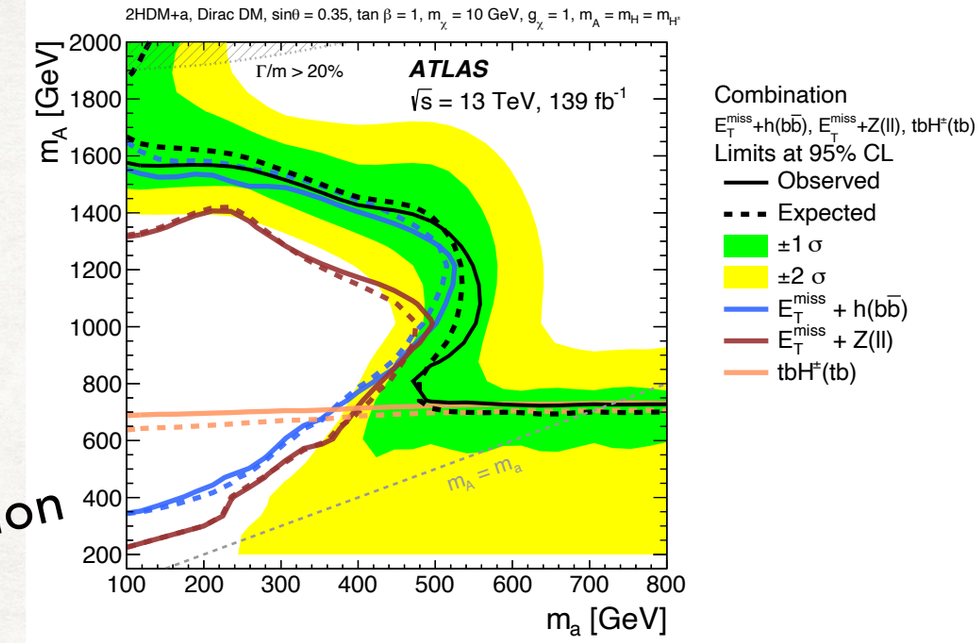
- $t\bar{t}t\bar{t}$: $t\bar{t} + A/H \rightarrow t\bar{t}t\bar{t}$ (JHEP 07 (2023) 203)
  - $m_H \in [400, 1000]$ GeV and width $\in [5, 30]$ GeV
  - Single and di-lepton triggers
  - Fit discriminant: BDT score



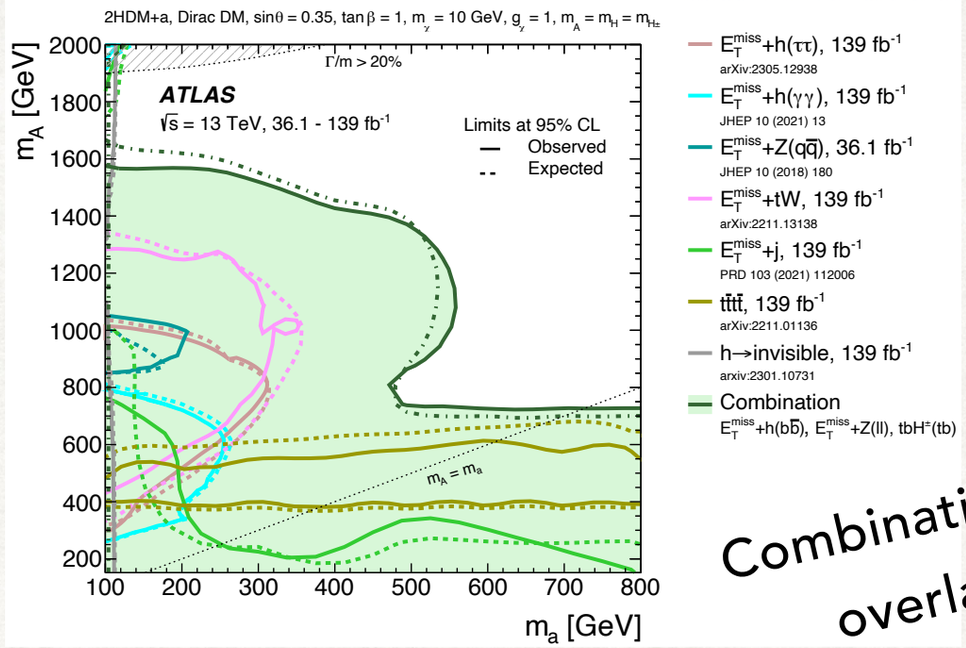
$m_a - m_A$ scans

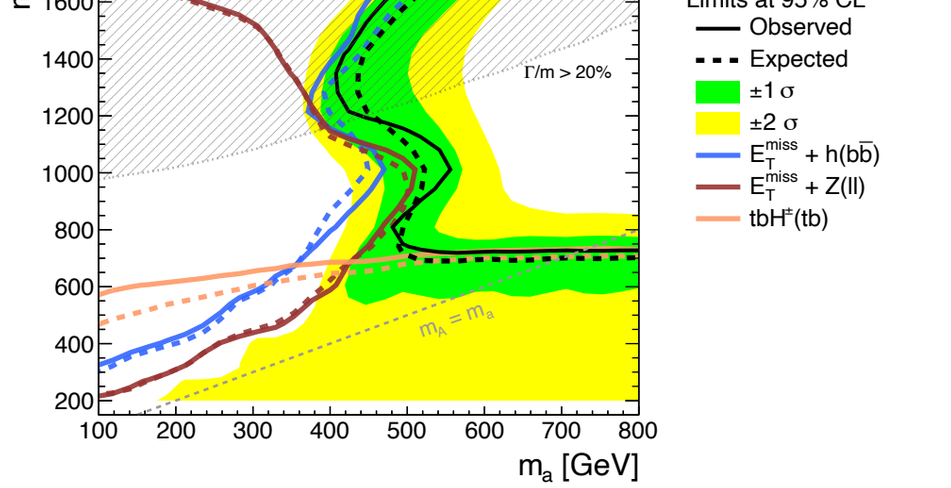
CERN-EP-2023-088

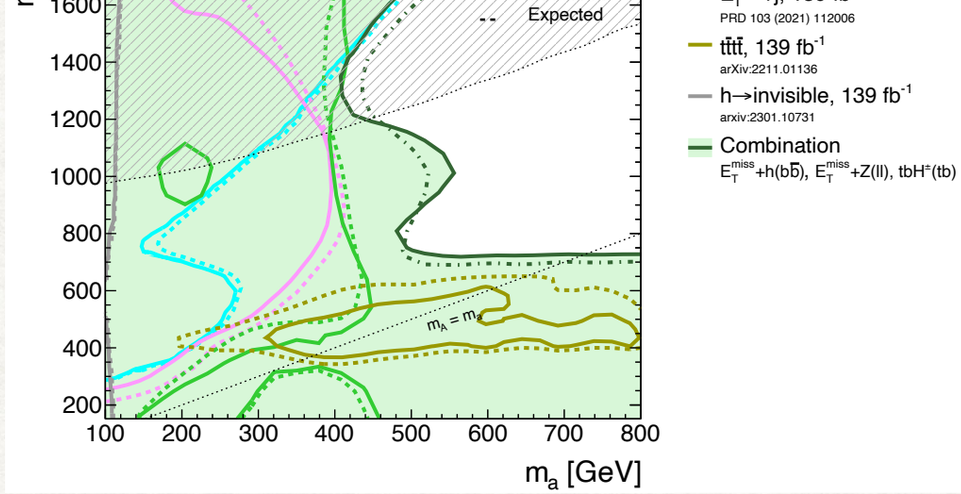
Combination



Combination & overlay



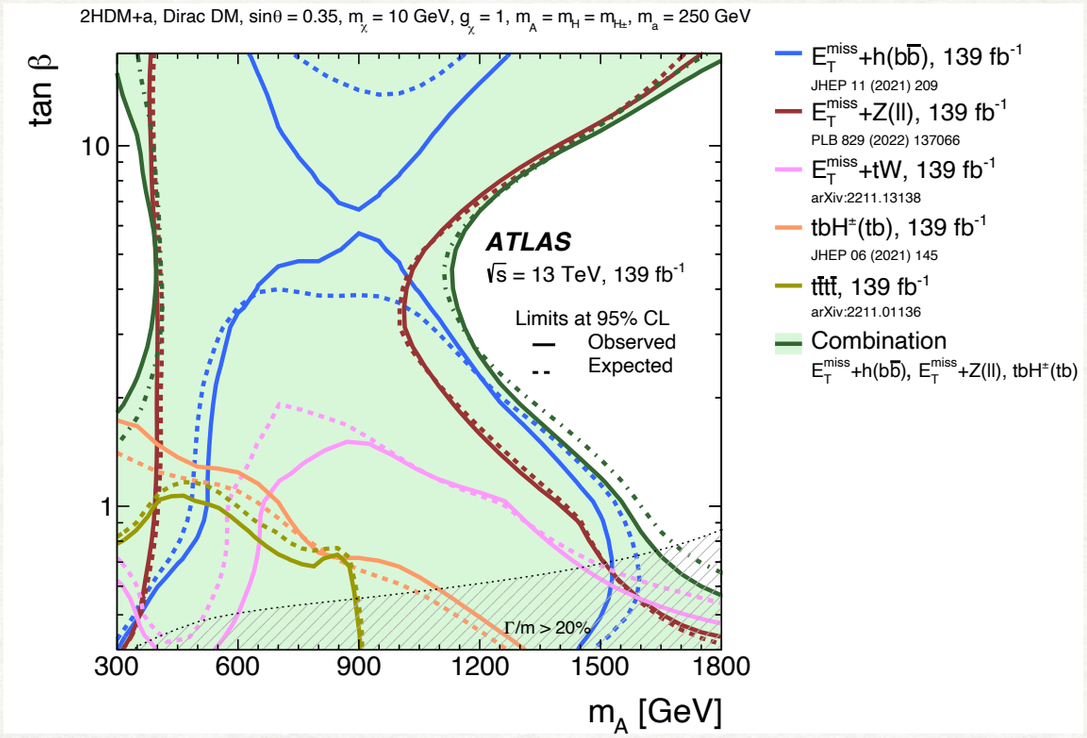


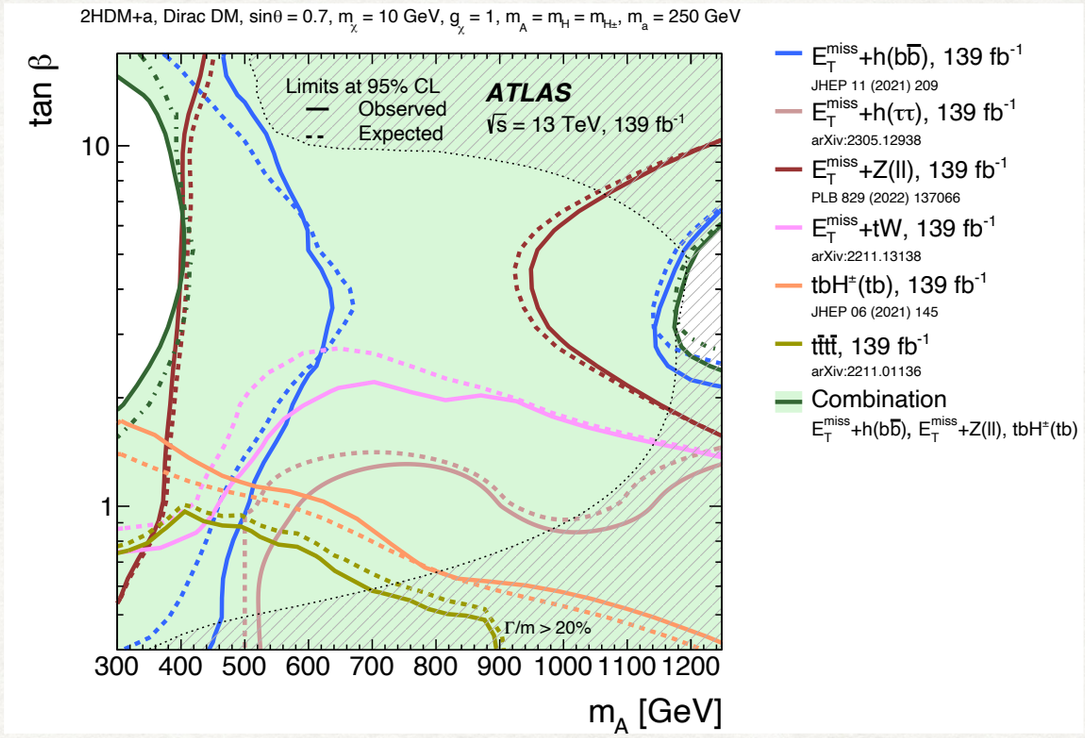


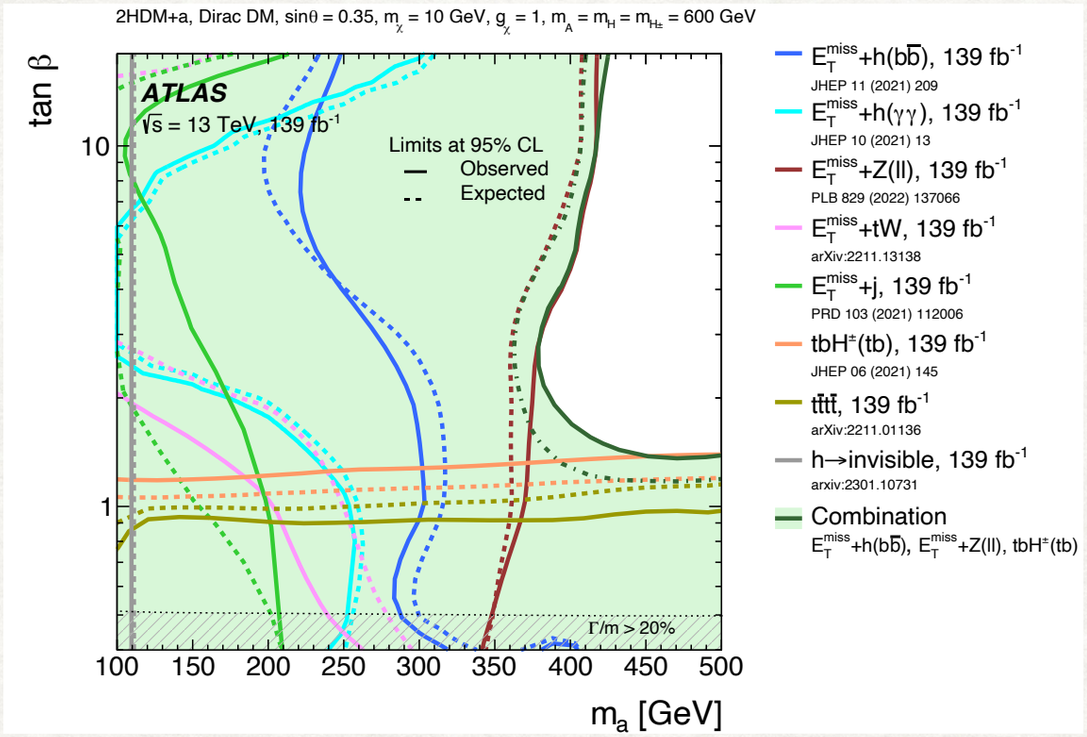
- For $sin\theta$ = 0.35, $m_A = m_H = m_H^{\pm}$ = 1.2 TeV, $\tan\beta$ = 1.0 m_a is excluded up to 560 GeV.
- For $sin\theta$ = 0.7, $m_A = m_H = m_H^{\pm}$ = 2 TeV, $\tan\beta$ = 1.0, m_a is excluded up to 640 GeV.
- $tbH^{\pm}(tb)$ is complementary to $E_T^{\text{miss}} + h(b\bar{b})$ and $E_T^{\text{miss}} + Z(ll)$: combination excludes $m_A \approx$ 800 (700) GeV for $sin\theta$ = 0.35 (0.7).
- The $t\bar{t}t\bar{t}$ is complementary to $E_T^{\text{miss}} + X$ and sensitive only if $m_{A/a} > 2m_t$.

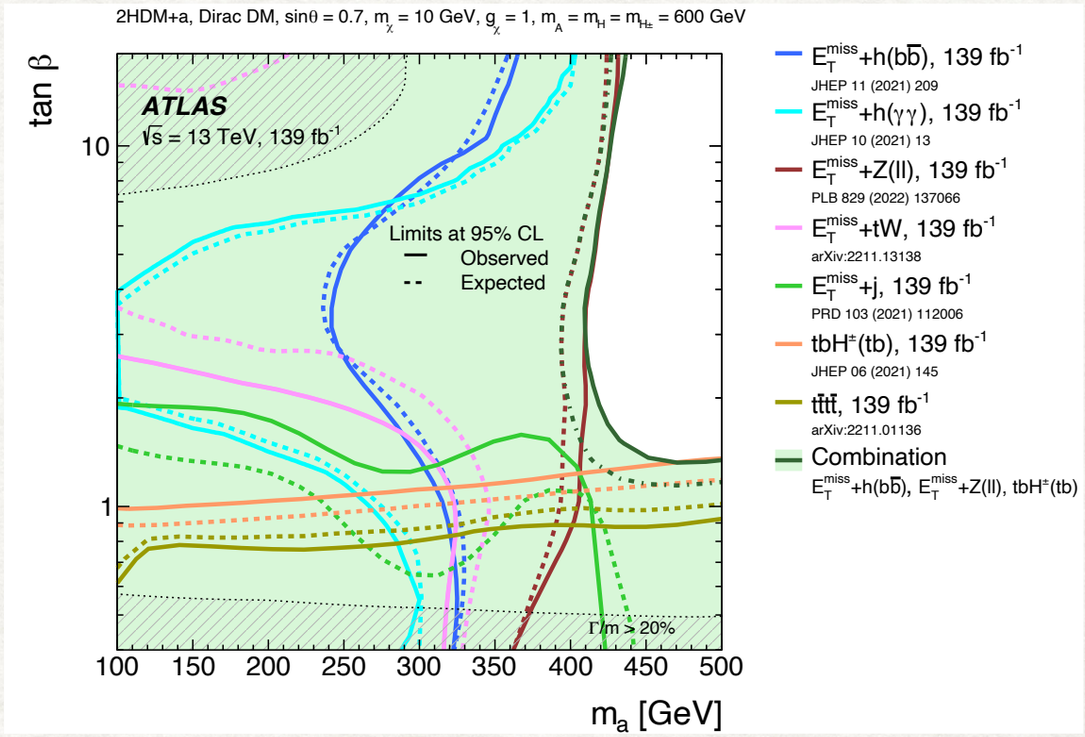
$m_{A/a} - tan\beta$ scans

CERN-EP-2023-088





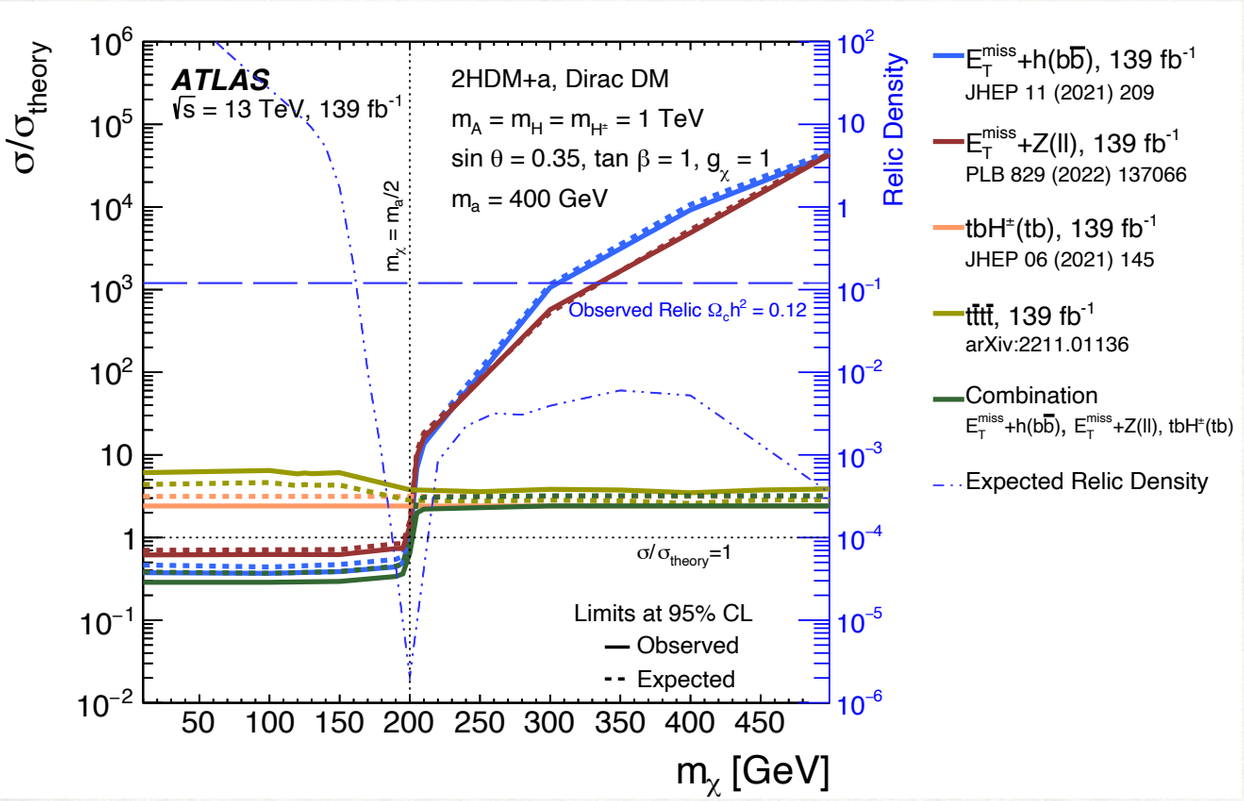


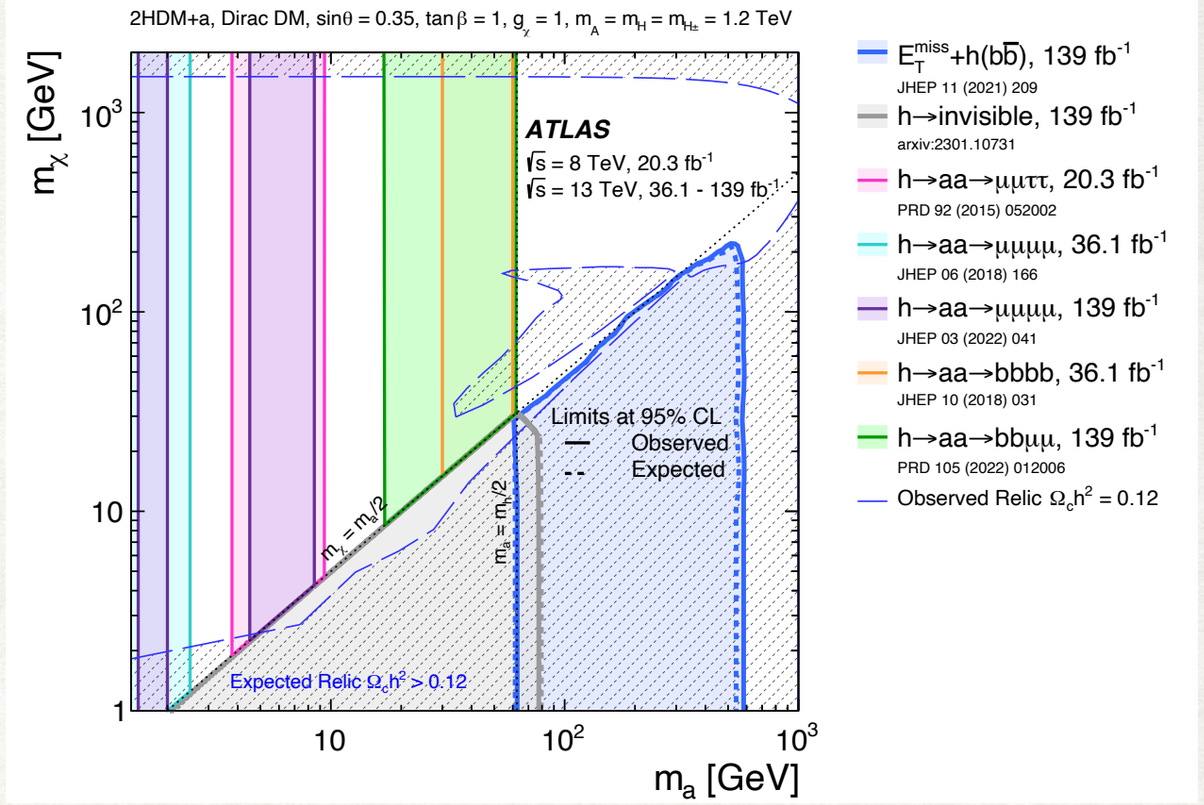


- Combination of $E_T^{\text{miss}} + h(b\bar{b})$, $E_T^{\text{miss}} + Z(ll)$, $tbH^{\pm}(tb)$ gives the strongest constraints in $m_A - tan\beta$ plane for both $sin\theta$ cases.
- For $m_a - tan\beta$ plane $E_T^{\text{miss}} + Z(ll)$ has the strongest exclusion: from $m_a \approx 350$ GeV for $tan\beta = 0.4$ to $m_a > 400$ GeV for $tan\beta \approx 10$.

m_χ scans

CERN-EP-2023-088





- m_χ - σ plane
  - Exclusion limits derived on the ratio of the excluded cross-section to the nominal cross-section of the model as a function of m_χ.
  - The parameter space of m_χ < 200 GeV is excluded by combination of $E_T^{\text{miss}} + h(b\bar{b})$ and $E_T^{\text{miss}} + Z(ll)$.
  - For $m_\chi > m_a/2$ the strongest constraints are obtained from $tbH^{\pm}(tb)$ but cannot exclude this $2HDM + a$ benchmark.
- $m_a - m_\chi$ plane
  - For m_A = 1.2 TeV, $\tan\beta$ = 1.0 and $\sin\theta$ = 0.35, $m_a > m_\chi/2$ region is excluded by $E_T^{\text{miss}} + h(b\bar{b})$ up to $m_a \approx$ 600 GeV.

Dark Photons

ANA-EXOT-2023-01

Combination of searches for the Higgs boson decaying into a photon and a massless dark photon using pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

The ATLAS Collaboration

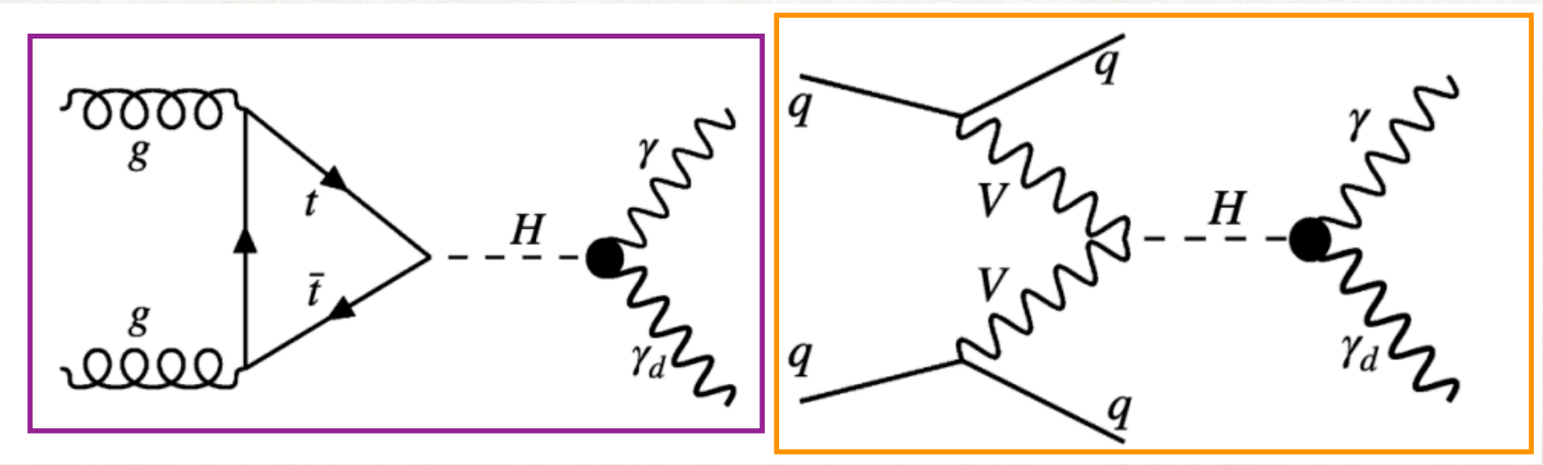
Analysis Overview

- Combining searches for Higgs boson (H_{BSM} and H) decaying into visible (γ) and massless dark photon (γ_d) using the full Run 2 ATLAS dataset.
- Model-independent search: targets $H_{BSM} \to \gamma\gamma_d$
- Analysis combines the following two analyses:

- $\gamma + E_T^{miss}$ (ggF channel) JHEP 02 (2021) 226)
  - 1-photon trigger and $E_T^{\gamma} > 150$ GeV
  - $m_{H_{BSM}} \in [400, 3000]$ GeV, narrow width
  - SRs based on E_T^{miss}
  - Fit discriminant: $\mathrm{E_T^{miss}}$

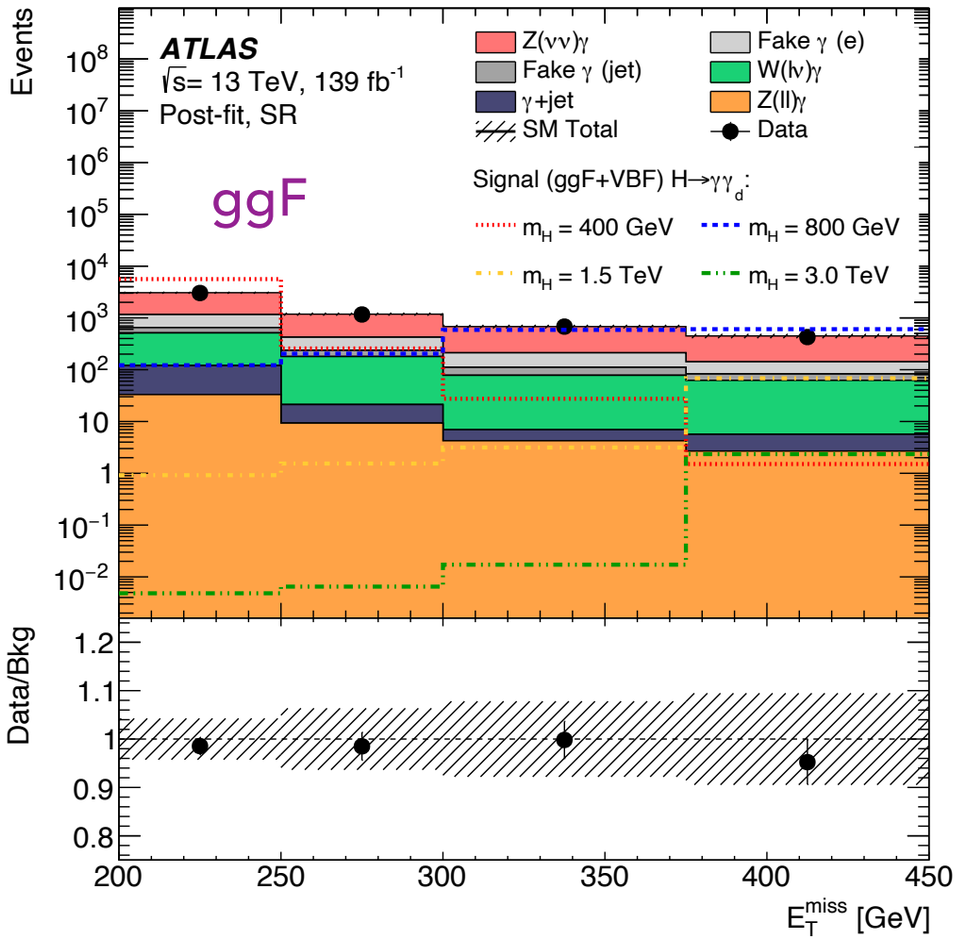
- $\gamma + E_T^{miss} + VBF$ jets (VBF channel) Eur. Phys. J. C 82 (2022) 105)
  - E_T^{miss} trigger with $E_T^{\mathrm{miss}} > 150$ GeV and single-lepton triggers for $W\gamma + jets$
  - $m_{H_{BSM}} \in [400, 3000]$ GeV, narrow width
  - SRs based on m_{jj} and m_T
  - Fit discriminant: $m_T(\gamma, \mathrm{E_T^{miss}})$

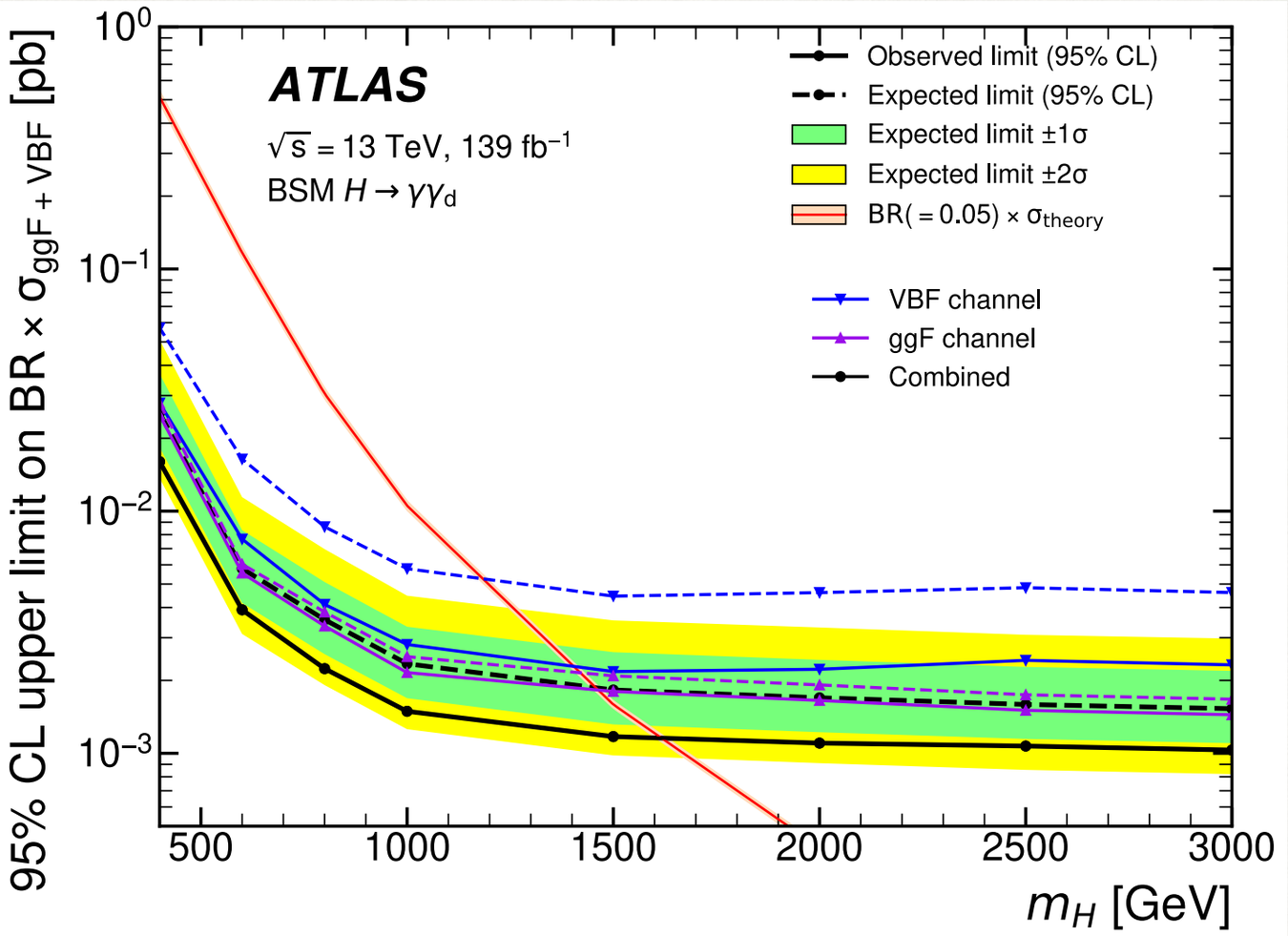
- In the VBF analysis the contribution of the ggF process to the H_{BSM} decay is included using RECAST.
- A profile-likelihood fit is performed across all channels to obtain the combined results.



Results

ANA-EXOT-2023-01





- No significant excess is observed: 95% CL exclusion limit on $\sigma_{ggF+VBF} \times BR(H_{BSM} \rightarrow \gamma\gamma_d)$ is derived as a function of $m_{H_{BSM}}$ where $\sigma_{ggF+VBF}$ is the combined H_{BSM} production cross-section.
- Exclusion limits on $\sigma_{ggF+VBF} \times BR(H_{BSM} \rightarrow \gamma\gamma_d)$:
  - Ranges from 16 fb for $m_{H_{BSM}}$= 400 GeV to 1.0 fb for $m_{H_{BSM}}$ = 3000 GeV.
  - Assuming a $BR(H_{BSM} \rightarrow \gamma\gamma_d)$ of 5%, $m_{H_{BSM}}$ < 1600 GeV are excluded.
  - The combination of ggF and VBF channel improves the $\sigma_{ggF+VBF} \times BR(H_{BSM} \rightarrow \gamma\gamma_d)$ limit at $m_{H_{BSM}}$= 1500 GeV by 33%.

Dark Higgs Boson

ATLAS-COM-CONF-2024-007

Search for dark matter produced in association with a dark Higgs boson in the $b\bar{b}$ final state using $\sqrt{s} = 13$ TeV collisions recorded with the ATLAS detector

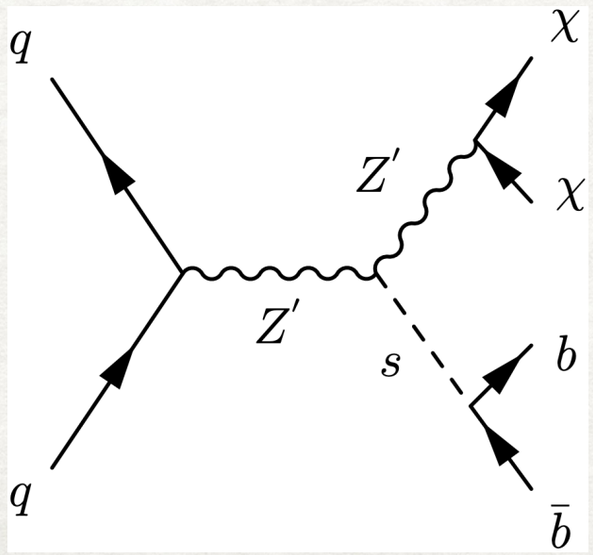
The ATLAS Collaboration

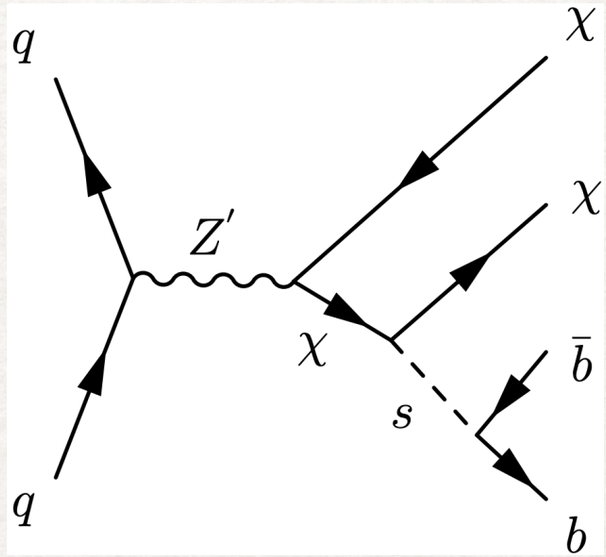
Analysis Overview

- Dark matter produced in association with a $b\bar{b}$ resonance with 30 < m_{bb} < 150 GeV using the full Run 2 ATLAS dataset.
- Benchmark model studied:
  - A dark Higgs model predicting production of DM particles (χ) with a new massive dark Higgs boson s and new Z' gauge boson JHEP 04 (2017) 143.
  - Model parameters: m_s, $m_{Z'}$, m_χ, coupling of Z' with quarks g_q and DM g_χ, mixing angle θ between SM and s.
- Analysis strategy:
  - Final state: E_T^{miss} + $b\bar{b}$ reconstructed in two different topologies:
    - Boosted: 1 b-tagged large-R (1.0) jet for m_s > 150 GeV, binned in E_T^{miss}: [500, 750], [750, ∞] GeV.
    - Resolved: 2 b-tagged small-R (0.4) jets for m_s < 150 GeV binned in E_T^{miss}: [150, 200], [200, 350], [350, 500] GeV.
  - Trigger: E_T^{miss} with E_T^{miss} > 150 GeV and single-lepton triggers.
  - Model parameter phase space studied:
    - Scenario 1: $m_s \in [30, 150]$ GeV, $m_{Z'}$ < 4 TeV, m_χ = 200 GeV, g_q = 0.25, g_χ = 1.0, and $\sin\theta$ = 0.01.
    - Scenario 2: $m_s \in [30, 150]$ GeV, $m_{Z'}$ < 4 TeV, m_χ = 900 GeV, g_q = 0.25, $\sin\theta$ = 0.01 and varying g_χ.
    - Scenario 3: scans ($m_{Z'}$, m_χ) plane, m_s = 70 GeV, g_q = 0.25, $\sin\theta$ = 0.01 and varying g_χ.

} $\Omega h^2 = 0.1200 \pm 0.0012$

  - A profile-likelihood fit is performed over all SR (using s mass distribution) and CRs simultaneously (using the yields).





Results

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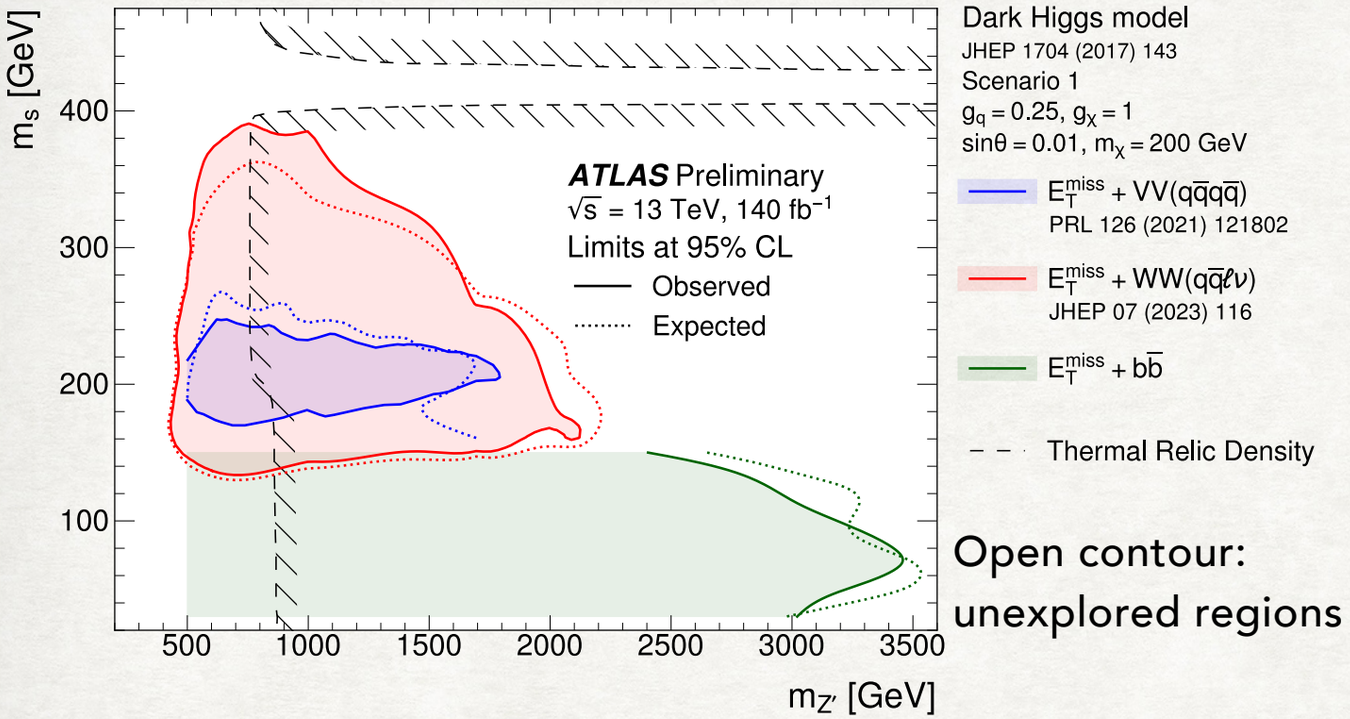
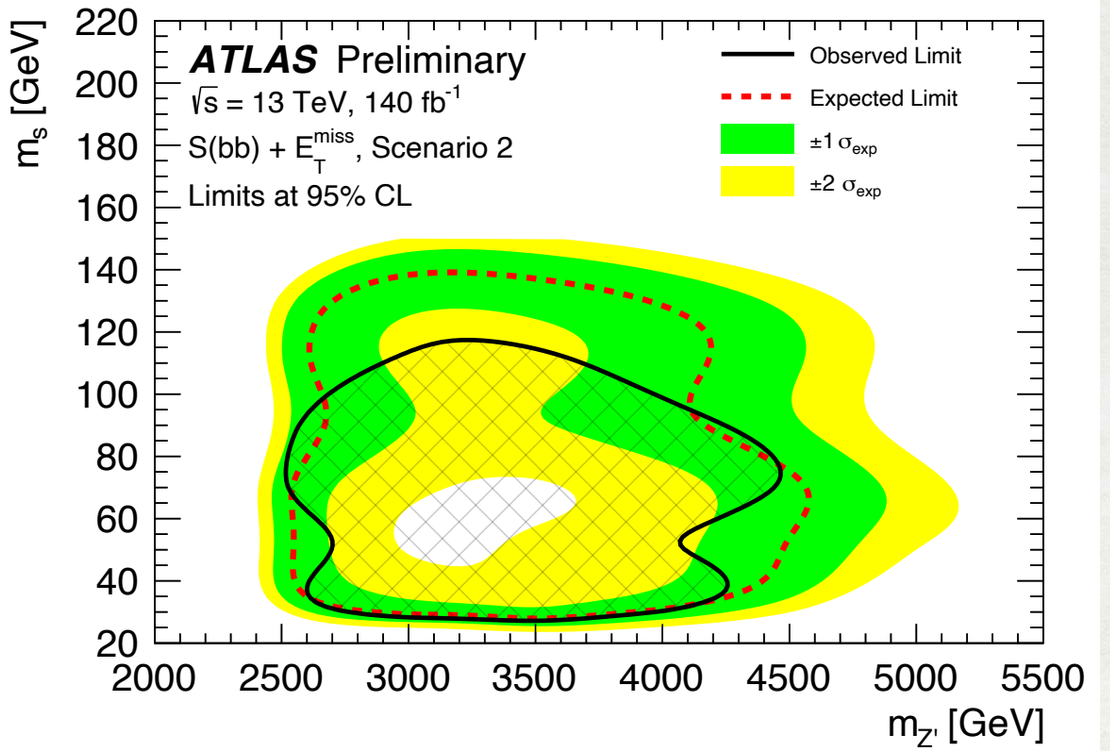
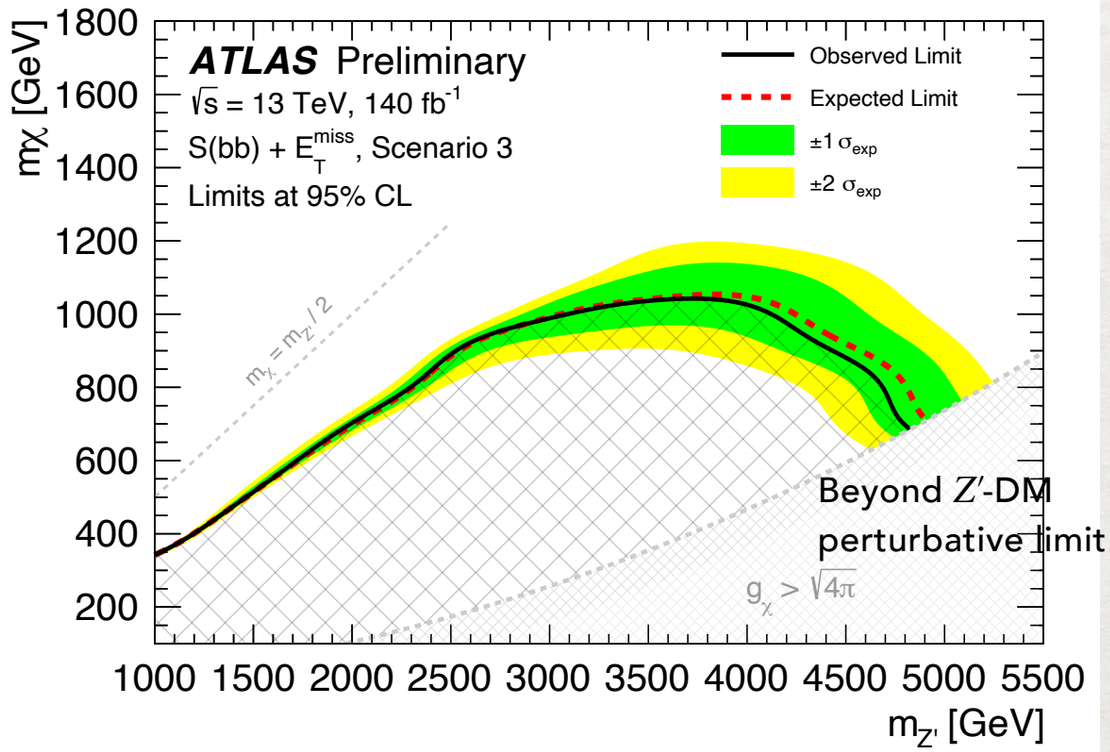


Open contour: unexplored regions



- No significant excess is observed: 95% CL exclusion limits on the model parameters are derived.
- Exclusion limits:
  - For g_χ = 1, g_q = 0.25, and m_s < 150 GeV, and $\sin\theta$ = 0.01, $m_{Z'}$ < 3.4 TeV are excluded.
  - For relic density-inspired models $m_{Z'}$ < 4.8 TeV are excluded.



Summary

- The latest ATLAS Run 2 results on Resonant Searches for Dark Matter Mediators are presented.
- Results highlights:
  - Mono-top: exclusion limits in different 2d parameter planes (m_ϕ, λ_q), (m_ϕ, y_χ), (m_ϕ, m_χ):
    - For λ_q = 0.6, y_χ = 0.4, and m_χ = 1 GeV, $m_\phi < 4.3$ TeV is excluded: improves the previous results by 800 GeV.
  - Dark-mesons: strongest exclusion limits on dark pion mass obtained from 1-lepton channel:
    - For η = 0.45, $m_{\pi D}$ < 940 GeV are excluded in the 1-lepton channel.
    - For η = 0.25, $m_{\pi D}$ < 740 GeV are excluded in the 1-lepton channel.
  - $2HDM + a$:
    - $E_T^{\text{miss}} + h(b\bar{b})$, $E_T^{\text{miss}} + Z(ll)$, $tbH^{\pm}(tb)$ are statistically combined.
    - Exclusion limits obtained on Type-II $2HDM + a$ parameter space: $m_a - m_A$, $m_{A/a} - \tan\beta$, $m_a - m_\chi$ etc.
  - Dark-photons: exclusion limit on $\sigma_{ggF+VBF} \times BR(H_{BSM} \to \gamma\gamma_d)$ is derived as a function of $m_{H_{BSM}}$:
    - Combining ggF and VBF channels improves the $\sigma_{ggF+VBF} \times BR(H_{BSM} \to \gamma\gamma_d)$ limit at $m_{H_{BSM}}$= 1.5 TeV by 33%.
  - Dark Higgs: exclusion limit on model parameters are derived:
    - For g_χ = 1, g_q = 0.25, and m_s < 150 GeV, and $\sin\theta$ = 0.01, $m_{Z'}$ < 3.4 TeV are excluded.
    - For relic density-inspired models $m_{Z'}$ < 4.8 TeV are excluded.

Back up

Mono top

Event Selections

Table 1: Summary of the event selections used to define the signal, control and validation regions. The signal regions are denoted by SR0b and SR1b, the $t\bar{t}$ (V+jets) dominated control regions are denoted by TCR (VCR) and the validation regions enhanced in $t\bar{t}$ (V+jets) are labelled as TVR1bLPhi, TVR1bHPhi and TVR2bHPhi (VVR). The "(1f)" notation in the signal and validation region rows indicates the additional requirement of at least one forward jet in the event, which is applied for the search of a single vector-like T quark. All regions are required in addition to contain zero leptons in the final state, $E_{\mathrm{T}}^{\mathrm{miss}} \geq 250$ GeV and at least one top-tagged large-R jets with $p_{\mathrm{T}} \in [350, 2500]$ GeV and a mass $\in [40, 600]$ GeV. The number of b-tagged (forward) jets required is indicated by $N_{b\text{-tagged jets}}$ ($N_{\text{forward-jets}}$). The symbol - indicates that no requirement on the variable is applied.

	$N_{b\text{-tagged jets}}$	$\Delta\phi_{\min}(j, E_{\mathrm{T}}^{\mathrm{miss}})$	XGBoost score	$N_{\text{forward jets}}$
TCR	≥ 2	$\in [0.2, 1]$	–	–
TVR1bLPhi	1	$\in [0.2, 1]$	–	–
TVR1bHPhi (1f)	1	≥ 1	< 0.5	– (≥ 1)
TVR2bHPhi	≥ 2	≥ 1	–	–
VCR	0	$\in [0.2, 1]$	–	–
VVR (1f)	0	≥ 1	< 0.5	– (≥ 1)
SR0b (1f)	0	≥ 1	≥ 0.5	– (≥ 1)
SR1b (1f)	1	≥ 1	≥ 0.5	– (≥ 1)

Regions

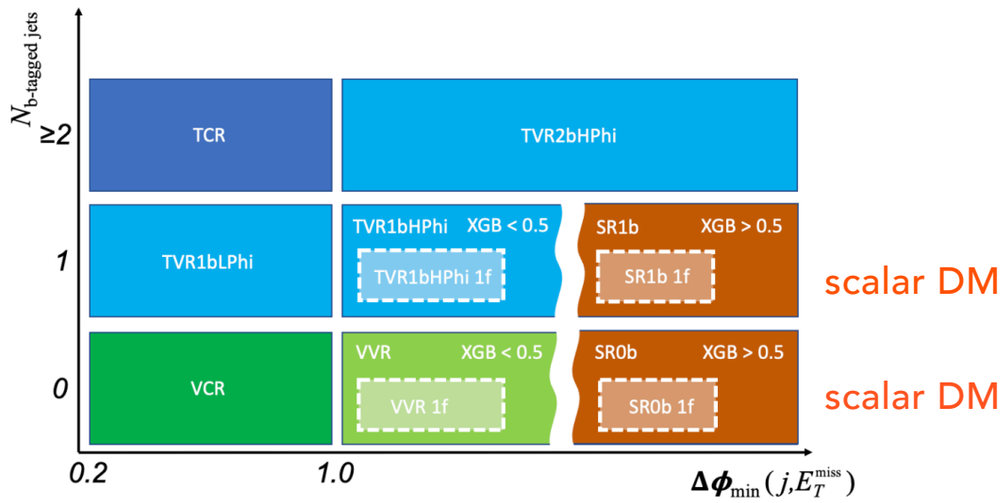
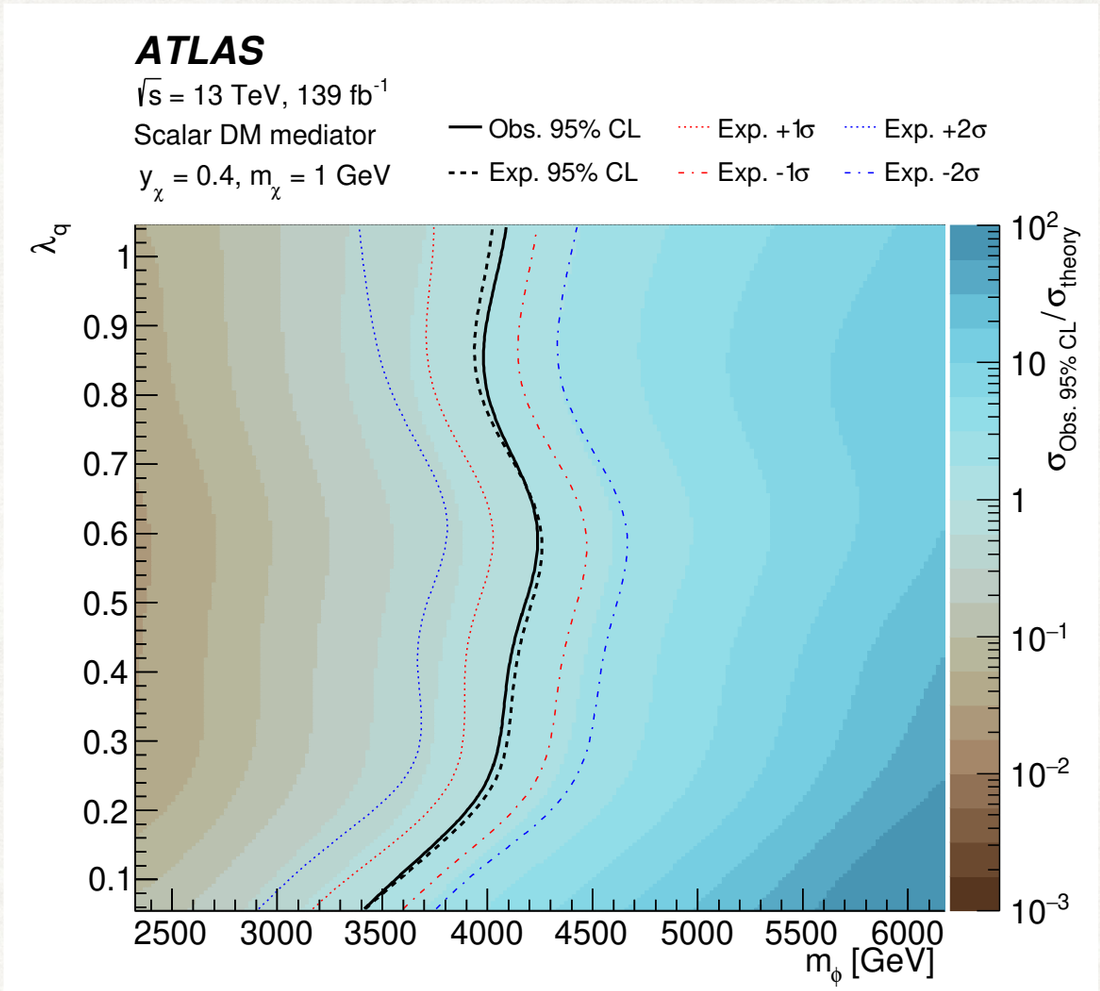


Figure 3: Schematic representation of the control, validation and signal regions. Regions are defined in terms of b-tagged jet multiplicity $N_{b\text{-tagged jets}}$ and the minimum distance in the azimuthal angle between a jet and $E_{\mathrm{T}}^{\mathrm{miss}}$ $\Delta\phi_{\min}(j, E_{\mathrm{T}}^{\mathrm{miss}})$. The notation "XGB<0.5" and "XGB>0.5" indicates the requirement on the XGBoost score of the validation and signal regions, respectively. These regions are schematically separated by the curly vertical line. The "1f" label stands for requiring at least one forward jet in the event. The selections used to define the regions are described in the text and in Table 1.

Variable	Description
$E_{\mathrm{T}}^{\mathrm{miss}}$	Missing transverse momentum
Ω	$E_{\mathrm{T}}^{\mathrm{miss}}$ and large-R jet p_{T} balance: $\frac{E_{\mathrm{T}}^{\mathrm{miss}} - p_{\mathrm{T}}(J)}{E_{\mathrm{T}}^{\mathrm{miss}} + p_{\mathrm{T}}(J)}$
N_{jets}	Small-R jet multiplicity
$\Delta R_{\max}$	Maximum ΔR between two small-R jets
$m_{\mathrm{T,min}}(E_{\mathrm{T}}^{\mathrm{miss}}, b\text{-tagged jet})$	Transverse mass of $E_{\mathrm{T}}^{\mathrm{miss}}$ and the closest b-tagged jet
$m_{\text{top-tagged jet}}$	Mass of the large-R top-tagged jet
Δp_{T} (J, jets)	Scalar difference of large-R jet p_{T} and the sum of p_{T} of all small-R jets.
H_{T}	Sum of all small-R jet p_{T}

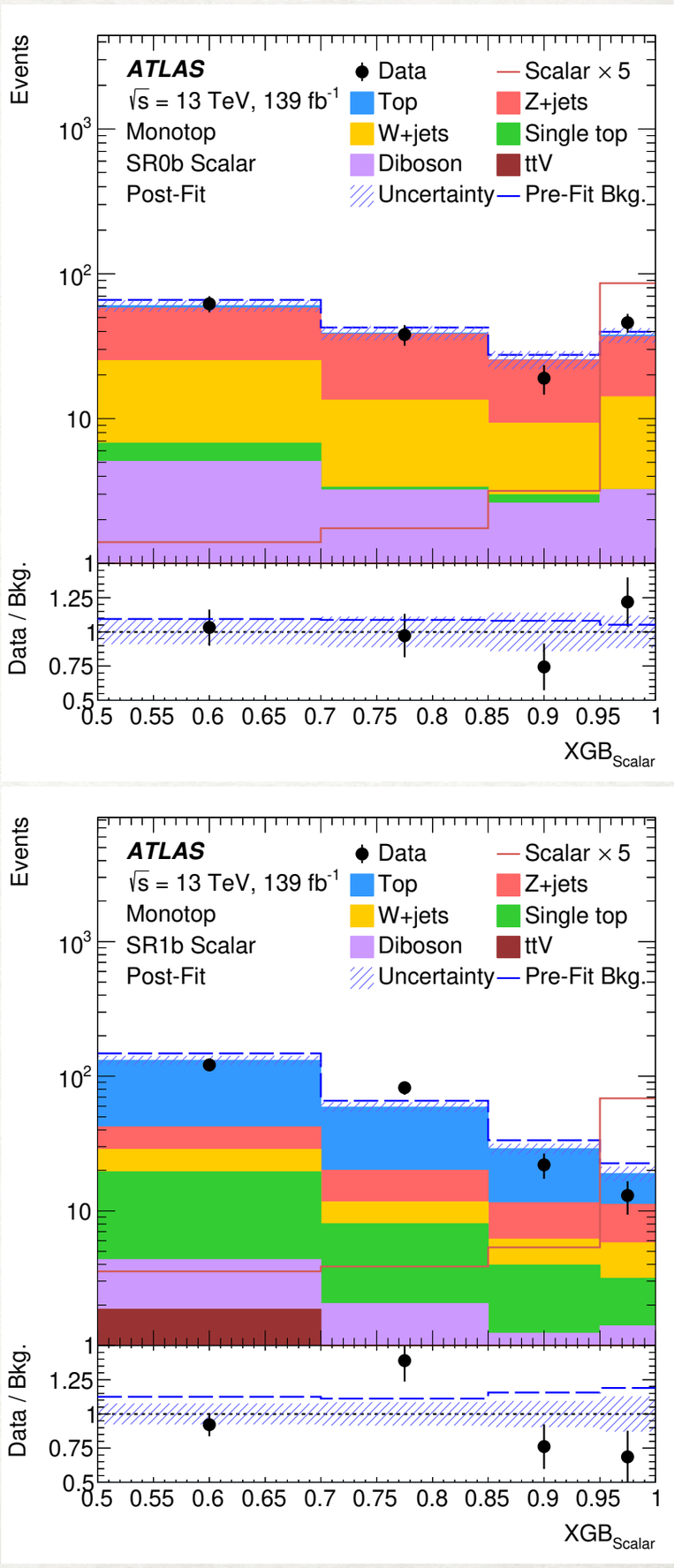
XGBoost

Mono top

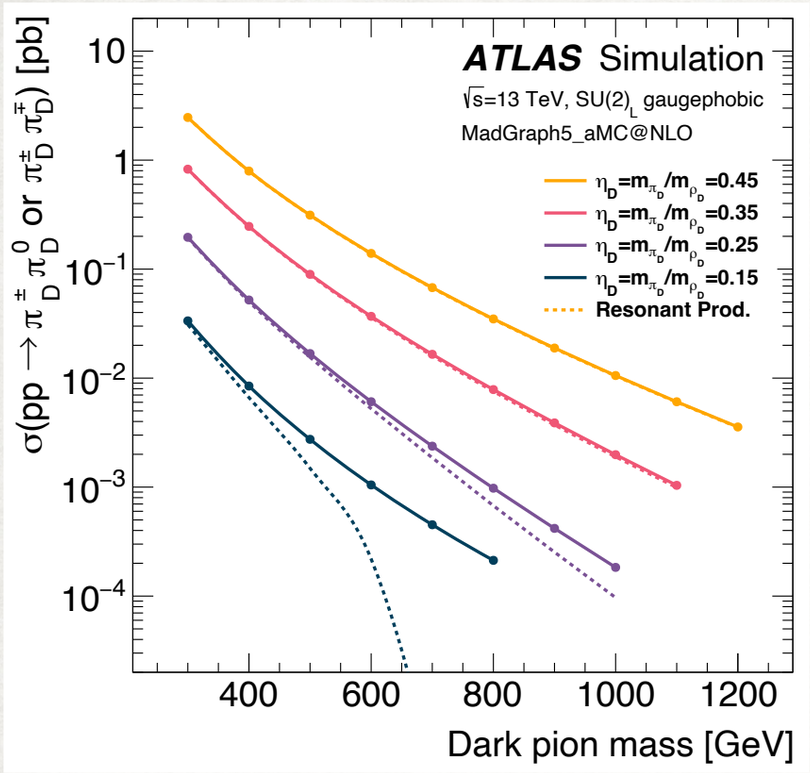


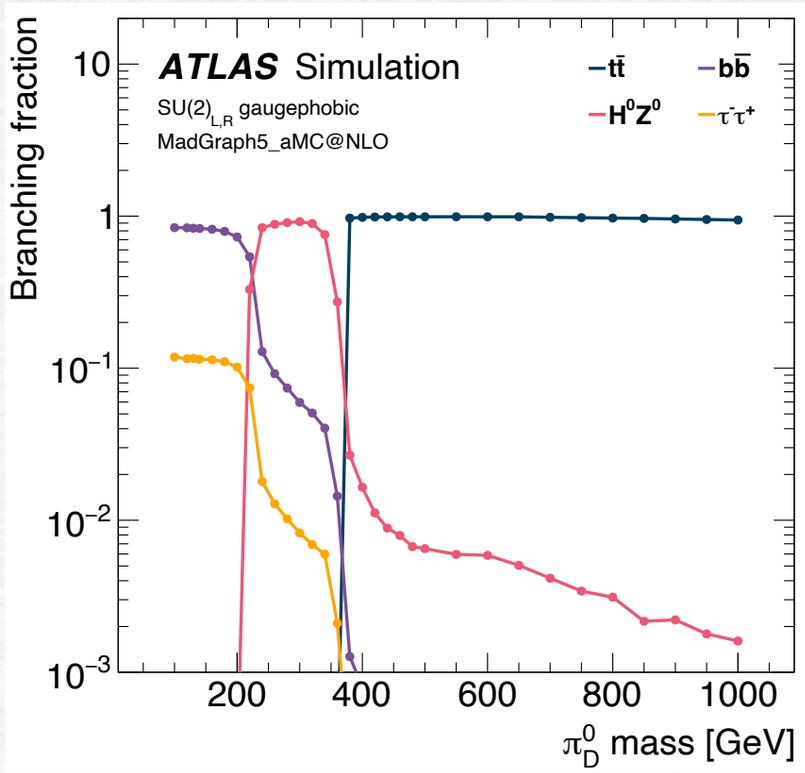
- No significant excess is observed: 95% CL exclusion limits on cross-section were obtained as a function of m_ϕ.
- For λ_q = 0.6, y_χ = 0.4 and m_χ = 1 GeV, $m_\phi < 4.3$ TeV is excluded: improves the previous results (JHEP 05 (2019) 41) by 800 GeV.

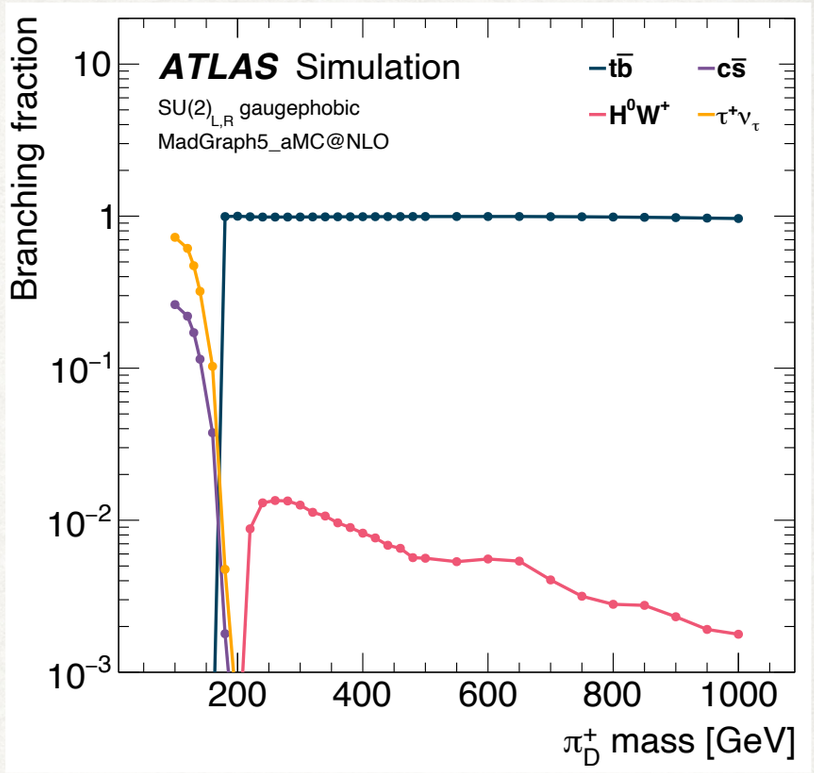
Post-fit

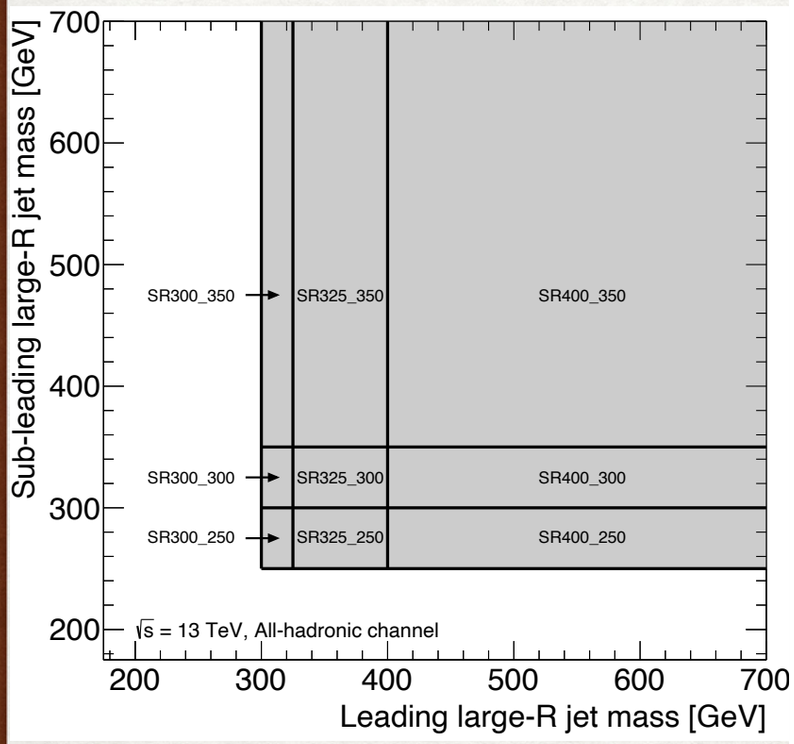


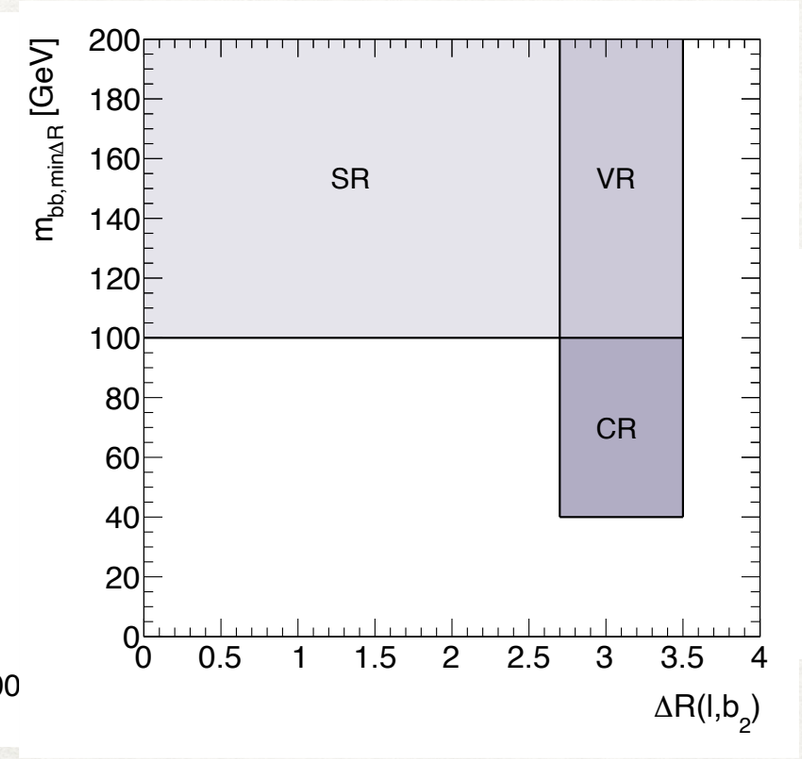
Dark Meson











Event Selections

Table 1: Summary of selection criteria for the SR ("Tag selection"). Nine bins are defined in the leading large-R jet, sub-leading large-R jet mass plane as also illustrated in Figure 4. The inverted selection ("Anti-tag selection") is also defined for use in the data-driven multijet extrapolation described in Section 6.

	Tag	Variable	Tag selection	Anti-tag selection
Both large-R jets		$m_{bb}/p_{\mathrm{T},bb}$	> 0.25	
Leading large-R jet	bb_1	$\Delta R\,(j, b_2)$	< 1.0	≥ 1.0
Sub-leading large-R jet	bb_2	$\Delta R\,(j, b_2)$	< 1.0	≥ 1.0
Leading large-R jet	$\pi_{D,1}$	$m_{\mathrm{jet,R=1.2}}$	[300 – 325 GeV, 325 – 400 GeV, > 400 GeV]	≤ 300 GeV
Sub-leading large-R jet	$\pi_{D,2}$	$m_{\mathrm{jet,R=1.2}}$	[250 – 300 GeV, 300 – 350 GeV, > 350 GeV]	≤ 250 GeV

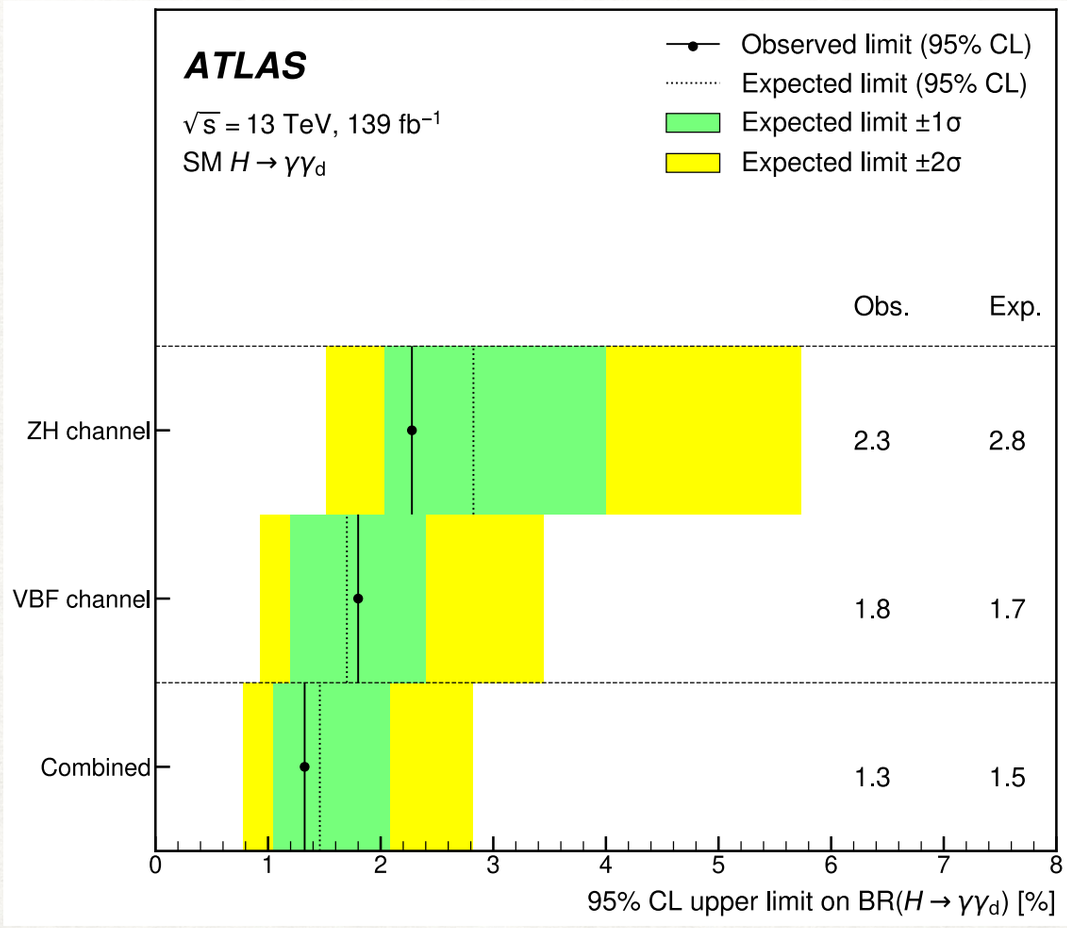
Dark Photon

Event Selections

Table 1: Summary of the event selections, discriminant and considered processes in the input channels used in this analysis.

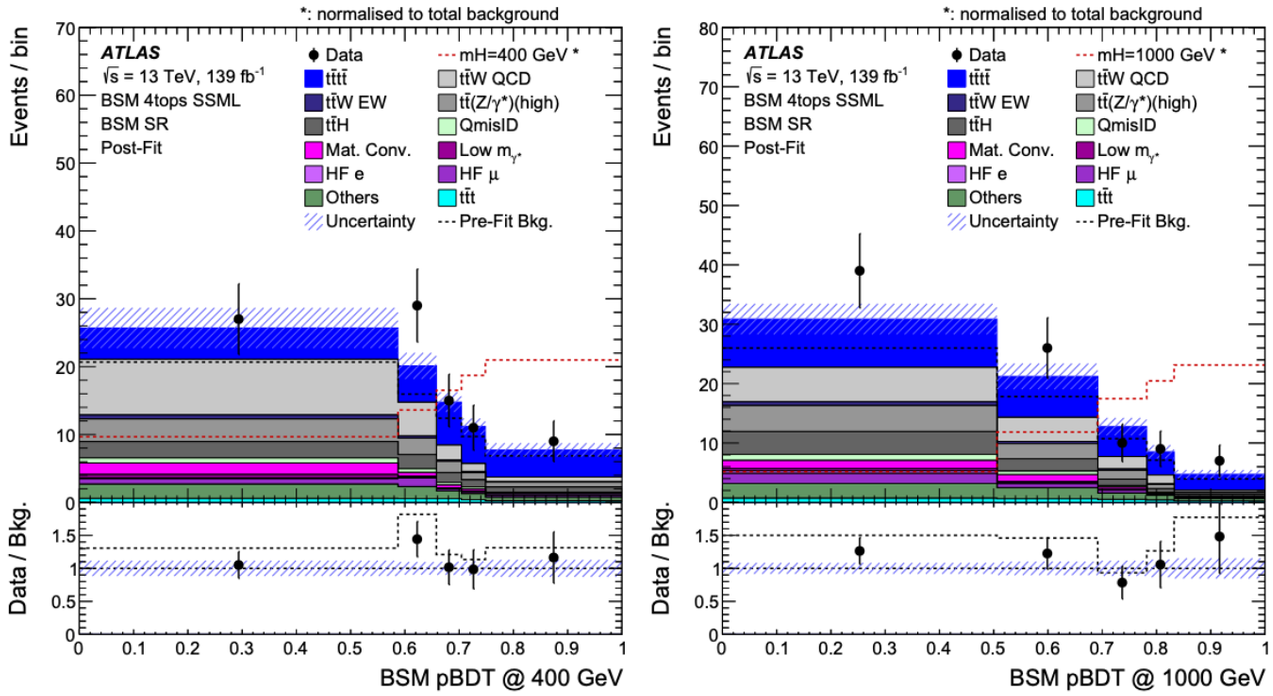
Channels	VBF	ZH	ggF
Trigger by	$E_{\mathrm{T}}^{\mathrm{miss}}$	Lepton(s)	Photon
Photons	1	1	≥ 1
E_{T}^{γ} [GeV]	$\in (15, \max(110, 0.733 \times m_{\mathrm{T}}))$	> 25	> 150
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 150	> 60	> 200
Jets	2 or 3, $m_{j_1 j_2} > 250\,\mathrm{GeV}$ $\lvert\Delta\eta_{j_1 j_2}\rvert > 3$, $\lvert\Delta\phi_{j_1 j_2}\rvert < 2$	≤ 2	≤ 1
Leptons	0 (e, μ)	2, $m_{\ell\ell} \in (76, 116)\mathrm{GeV}$	0 (e, μ, τ)
Discriminant	m_{jj} and m_{T} in SR and 4 CRs	BDT score and 1 CR	$E_{\mathrm{T}}^{\mathrm{miss}}$
Considered processes	VBF (and ggF added for this combination)	ZH	VBF, ggF
Combination scenario	SM, BSM	SM	BSM
Reference	[26]	[27]	[28]

SM Higgs



2HDM+a 4 top

Region	Channel	N_j	N_b	Other selection requirements	Fitted variable
CR Conv	$e^{\pm}e^{\pm}$ || $e^{\pm}\mu^{\pm}$	$4 \leq N_j < 6$	≥ 1	$m_{ee}^{CV} \in [0, 0.1]$ GeV $200 < H_T < 500$ GeV	m_{ee}^{PV}
CR HF e	eee || $ee\mu$		$= 1$	$100 < H_T < 250$ GeV	Yield
CR HF μ	$e\mu\mu$ || $\mu\mu\mu$		$= 1$	$100 < H_T < 250$ GeV	Yield
CR $t\bar{t}W$	$e^{\pm}\mu^{\pm}$ || $\mu^{\pm}\mu^{\pm}$	≥ 4	≥ 2	$m_{ee}^{CV} \notin [0, 0.1]$ GeV, $\|\eta(e)\| < 1.5$ for $N_b = 2$, $H_T < 500$ GeV or $N_j < 6$; for $N_b \geq 3$, $H_T < 500$ GeV	$\sum p_T^{\ell}$
CR lowBDT	SS+3L	≥ 6	≥ 2	$H_T > 500$ GeV, SM BDT < 0.55	SM BDT
BSM SR	SS+3L	≥ 6	≥ 2	$H_T > 500$ GeV, SM BDT ≥ 0.55	BSM pBDT



(a) (b)

Figure 6: Data and post-fit background comparison obtained with the background-only fit to the *BSM SR* for the BSM pBDT distribution used for (a) $m_H = 400$ GeV and (b) $m_H = 1000$ GeV. The fit is done simultaneously in all signal and control regions. The band includes the total uncertainty of the post-fit estimate. The respective signal hypothesis is also shown. The signal is normalised to the total background for better visibility. The total background prediction before the likelihood fit to data ('Pre-Fit Bkg.') is shown as a dashed black line. The ratio of the data to the background prediction is shown in the lower panel, separately for post-fit background (black points) and pre-fit background (dashed black line). The binning of the BSM pBDT is optimised for every signal hypothesis to provide the best discrimination between the tested signal and the background, avoiding the presence of bins with no contribution from the major backgrounds.

Two Higgs Doublet Model (2HDM+a)

✦ The 2HDM model contains 2 Higgs doublets and 5 Higges:

- two neutral CP-even H and h
- one neutral CP-odd A
- two charged Higgs bosons $H^{\pm}$

✦ Model parameters:

- Masses of the Higgses: $m_A, m_H, m_{H^{\pm}}, m_h$

- $m_A = m_{H^{\pm}}$, $m_H = m_{H^{\pm}}$ and $h = 125$ GeV

- $H_{SM} = hsin(\alpha - \beta) - Hcos(\alpha - \beta) : H_{SM} = h$ for $cos(\beta - \alpha) = 0$ (alignment limit), α and β are mixing angles between H, h and $H^{\pm}, A$ respectively; $tan\beta = v_1/v_2$ where v's are the vacuum expectation values of the Higgs doublets.

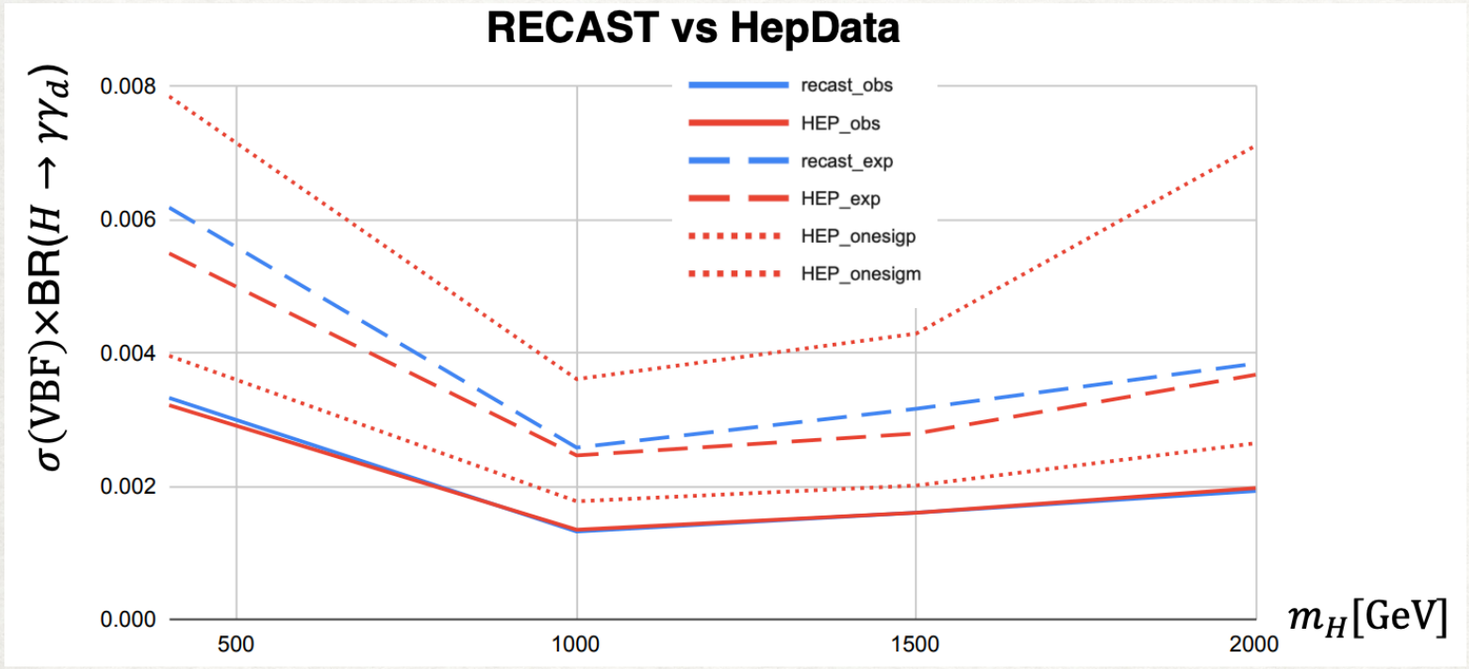
- To be consistent with SM: $v = \sqrt{v_1^2 + v_2^2} \approx$ 246 GeV

- λ_3: coupling constant between scalar doublets

Dark Photon: Recast

- Used VBF RECAST since original VBF samples/derivations/workspaces were lost.
  - VBF recast workflow (link)
    - Signal DAOD → mini/macro Ntuples → HistFitter inputs → Workspace and limits
  - Producing VBF+ggF workspaces/limits for Heavy Higgs

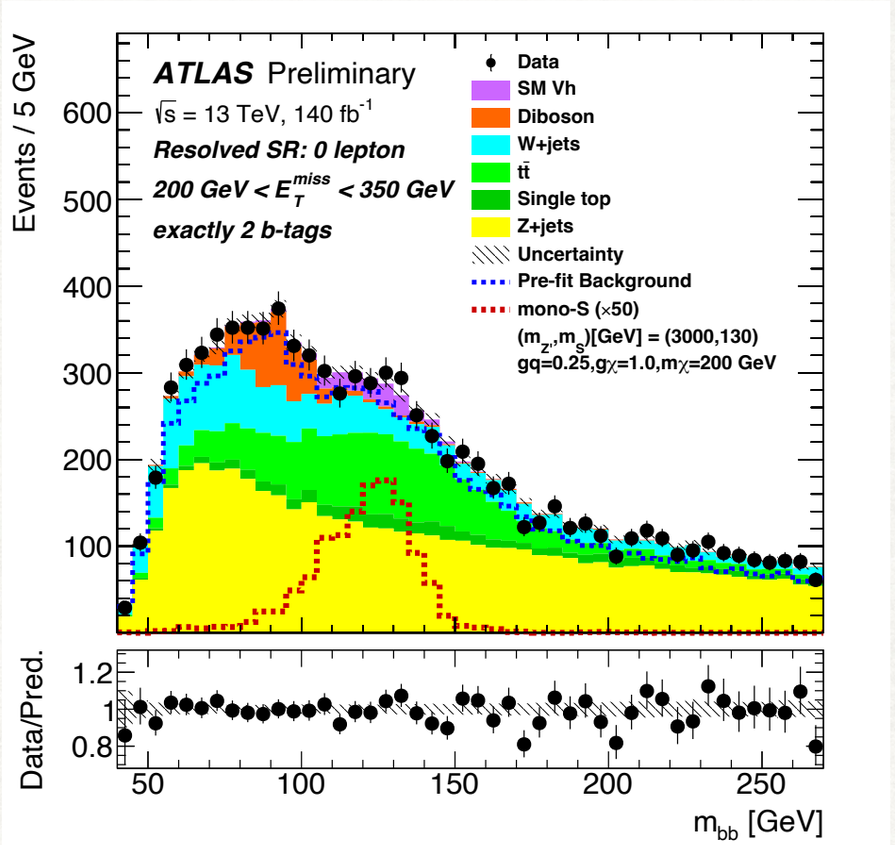
- Results mostly have good agreement with HepData

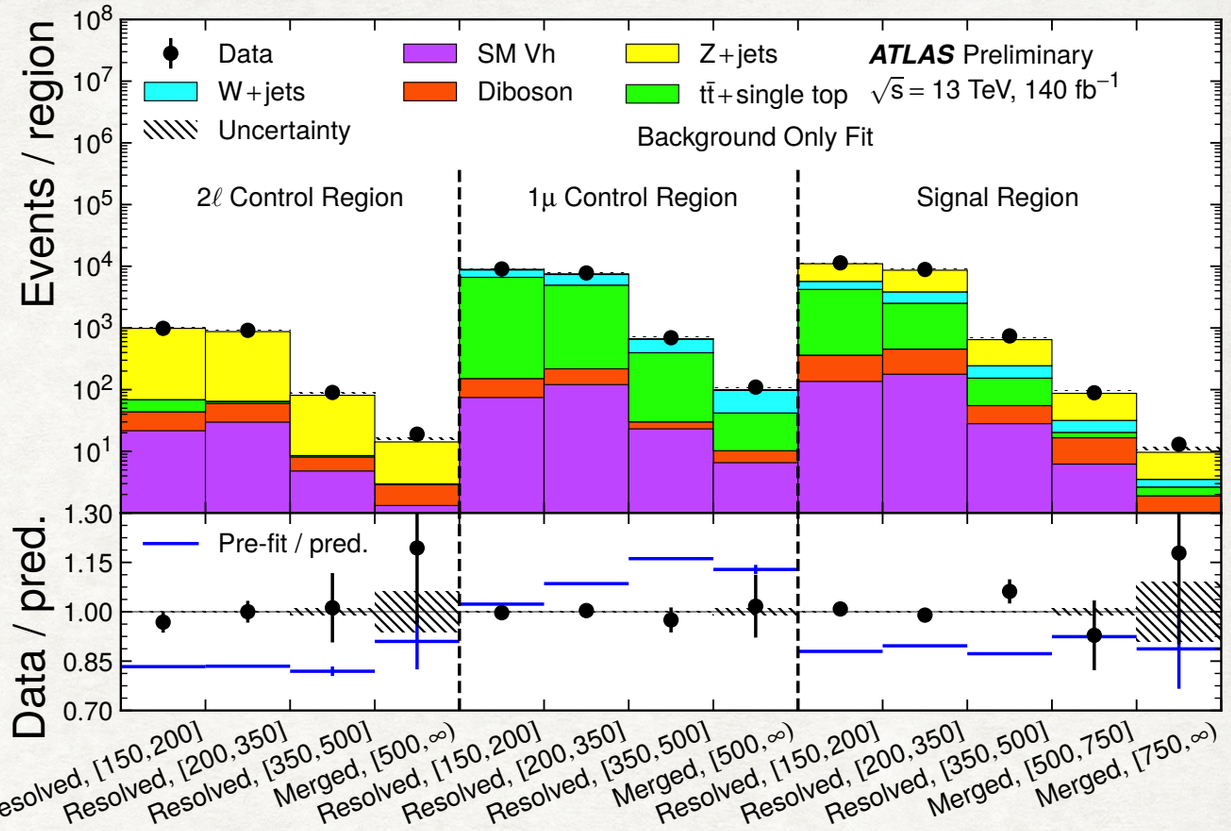


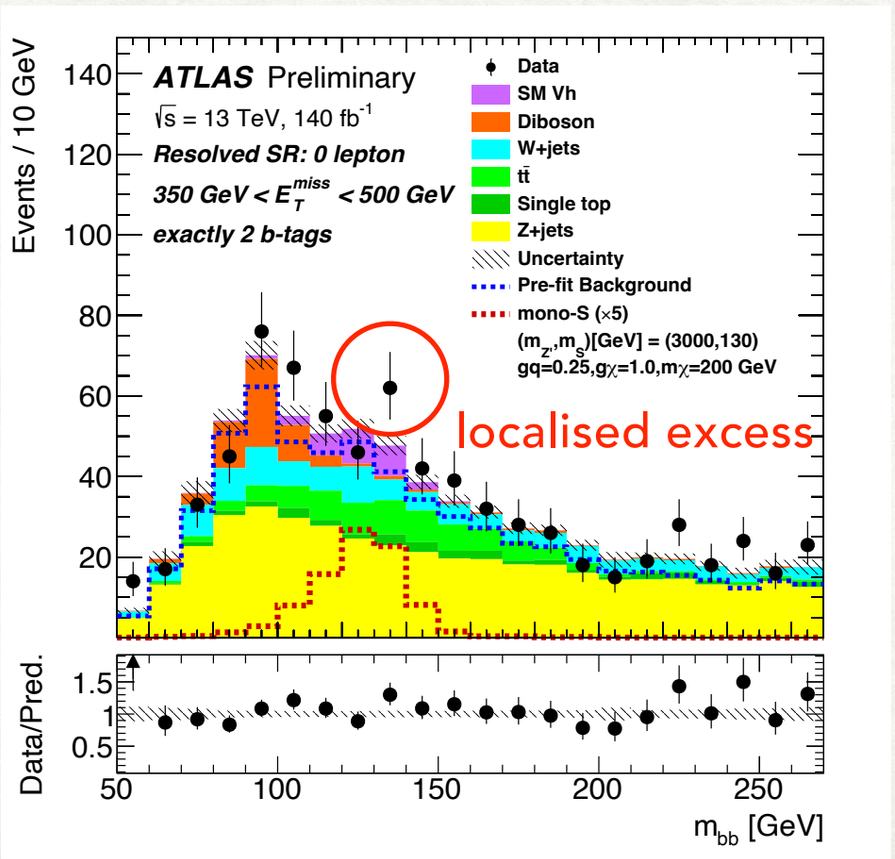
m_H	Obs. Diff%	Exp. Diff%
125 GeV	1.75	-1.60
400 GeV	3.42	12.51
1000 GeV	-2.02	4.76
2000 GeV	-2.23	4.55

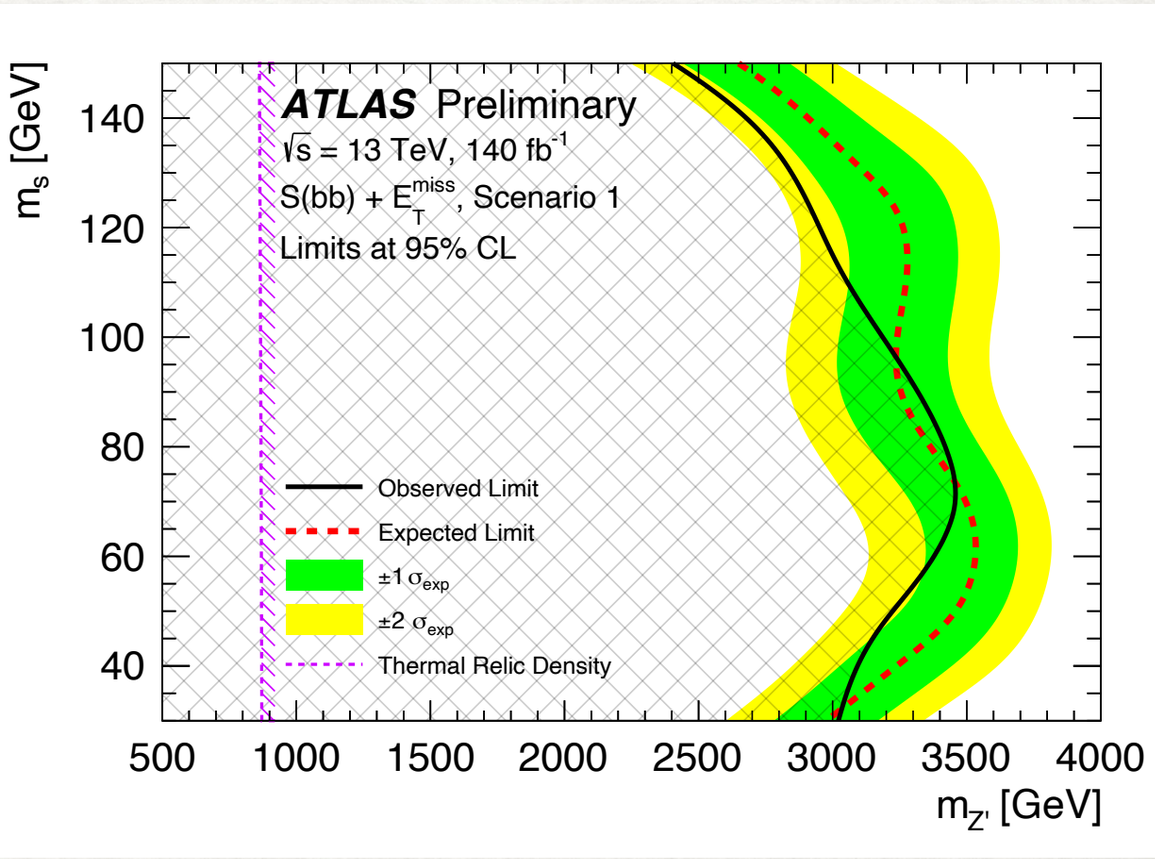
$$Diff = \frac{Recast - Paper}{Paper}\%$$

Dark Higgs


ATLAS Preliminary
√s = 13 TeV, 140 fb-1
Resolved SR: 0 lepton
200 GeV < E_T^miss < 350 GeV
exactly 2 b-tags
Data
SM Vh
Diboson
W+jets
tt̄
Single top
Z+jets
Uncertainty
Pre-fit Background
mono-S (×50)
(m_Z',m_S)[GeV] = (3000,130)
gq=0.25,gχ=1.0,mχ=200 GeV
Events / 5 GeV
Data/Pred.
m_bb [GeV]


Data
SM Vh
Z+jets
ATLAS Preliminary
√s = 13 TeV, 140 fb-1
W+jets
Diboson
tt̄+single top
Uncertainty
Background Only Fit
2ℓ Control Region
1μ Control Region
Signal Region
Events / region
Pre-fit / pred.
Data / pred.
Resolved, [150,200]
Resolved, [200,350]
Resolved, [350,500]
Merged, [500,∞)
Merged, [500,750]
Merged, [750,∞)


ATLAS Preliminary
√s = 13 TeV, 140 fb-1
Resolved SR: 0 lepton
350 GeV < E_T^miss < 500 GeV
exactly 2 b-tags
Data
SM Vh
Diboson
W+jets
tt̄
Single top
Z+jets
Uncertainty
Pre-fit Background
mono-S (×5)
(m_Z',m_S)[GeV] = (3000,130)
gq=0.25,gχ=1.0,mχ=200 GeV
localised excess
Events / 10 GeV
Data/Pred.
m_bb [GeV]


ATLAS Preliminary
√s = 13 TeV, 140 fb-1
S(bb) + E_T^miss, Scenario 1
Limits at 95% CL
Observed Limit
Expected Limit
±1 σ_exp
±2 σ_exp
Thermal Relic Density
m_s [GeV]
m_Z' [GeV]

Low Mass Resonance to dijet

Search for low-mass resonances decaying into two jets and produced in association with a photon or a jet at $\sqrt{s} = 13$ TeV with the ATLAS detector

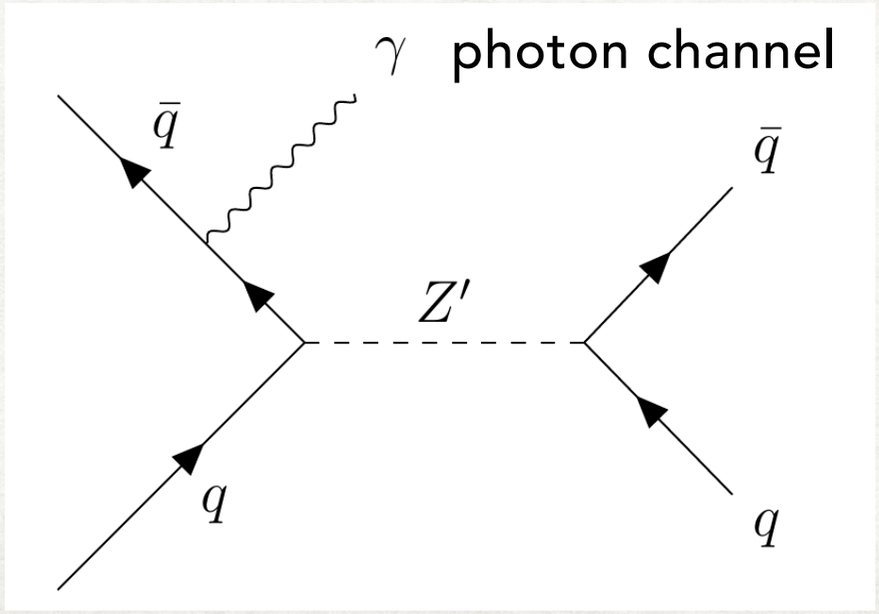
The ATLAS Collaboration

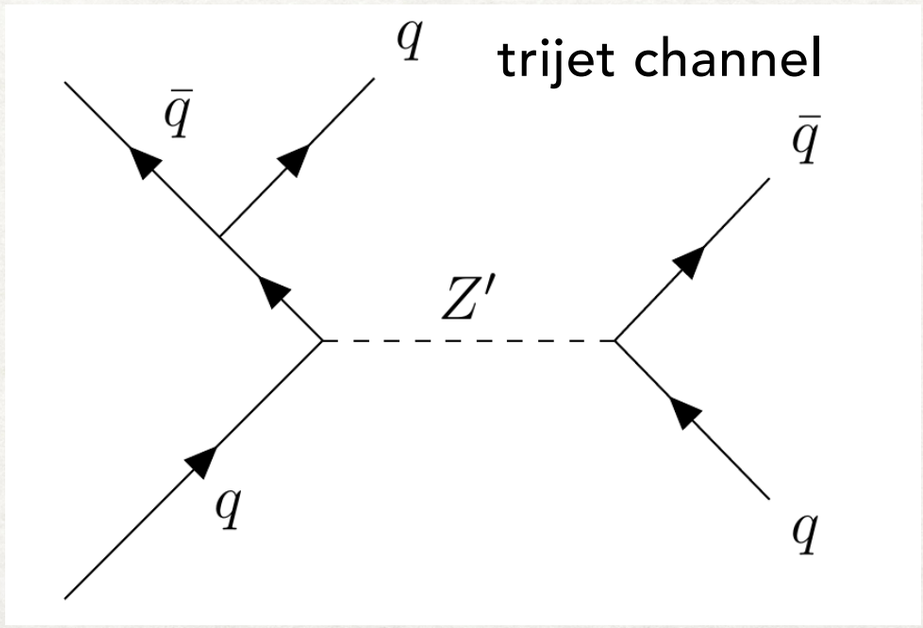
A search is performed for localized excesses in the low-mass dijet invariant mass distribution, targeting a hypothetical new particle decaying into two jets and produced in association with either a high transverse momentum photon or a jet. The search uses the full Run 2 data sample from LHC proton–proton collisions collected by the ATLAS experiment at a center-of-mass energy of 13 TeV during 2015–2018. Two variants of the search are presented for each type of initial-state radiation: one that makes no jet flavor requirements and one that requires both of the jets to have been identified as containing b-hadrons. No excess is observed relative to the Standard Model prediction, and the data are used to set upper limits on the production cross-section for a benchmark Z' model and, separately, for generic, beyond the Standard Model scenarios which might produce a Gaussian-shaped contribution to dijet invariant mass distributions. The results extend the current constraints on dijet resonances to the mass range between 200 and 650 TeV.

CERN-EP-2024-044

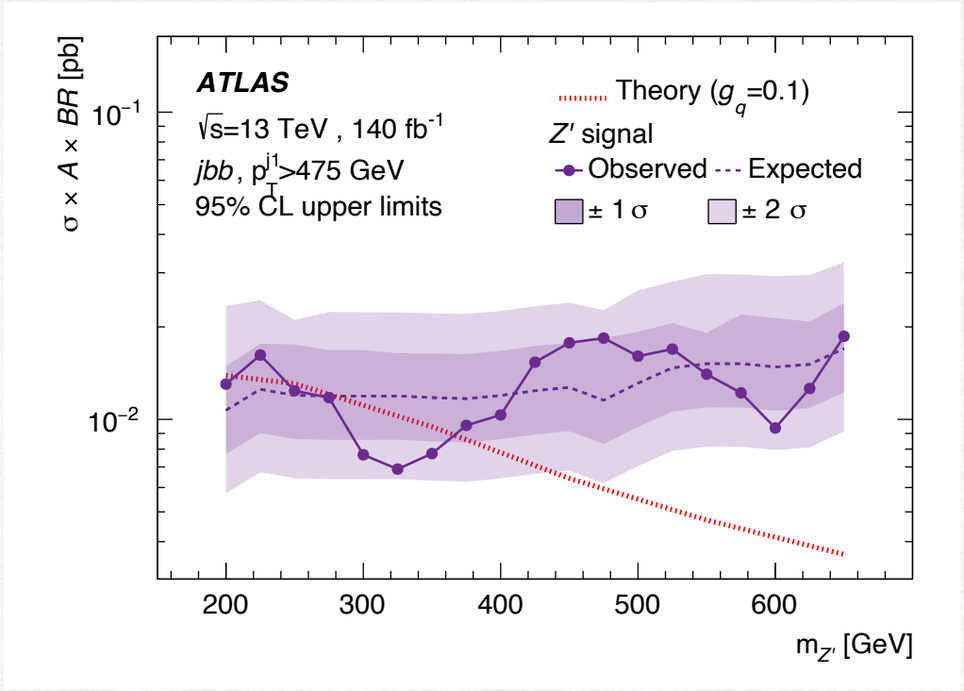
Analysis Overview

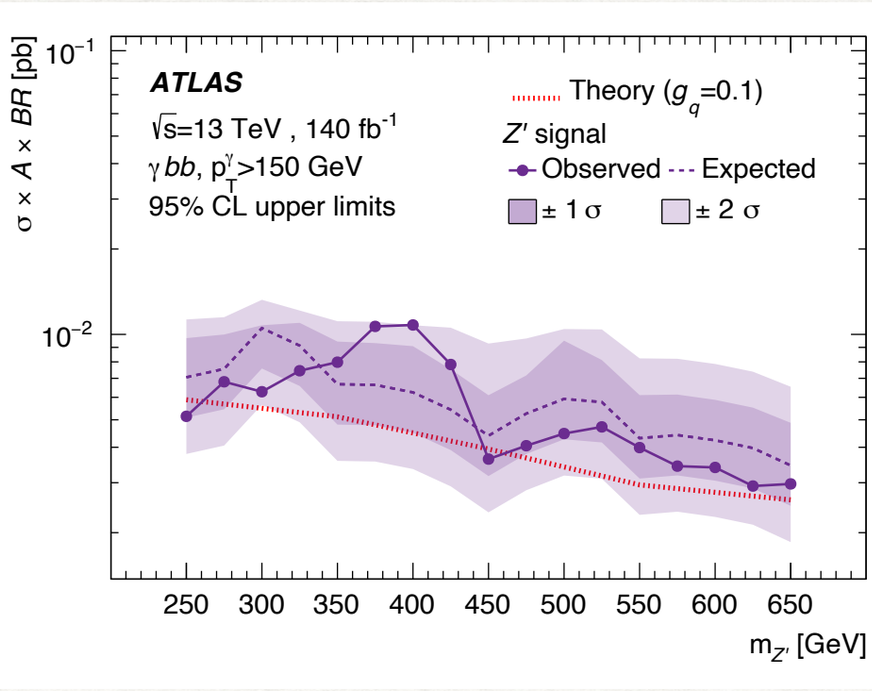
- Search for a mediator particle produced in association with a high p_T photon/jet decaying into two jets using full Run2 ATLAS dataset.
- Benchmark models studied:
  1. Z' model where Z' is a spin-1 vector boson, which could be a DM candidate (arxiv1506.03116) .
  2. Generic BSM scenarios which might produce a Gaussian-shaped contribution to dijet invariant mass distributions.
- Analysis strategy:
  - To probe low mass regions the analysis relies on ISR jet or photon: enabling access to lower dijet masses without trigger bias.
  - Signal: $m_{Z'}$: 200-650 GeV, $g_q = 0.2$ (coupling between Z′ and non-top quarks)
  - Final states: γjj, γbb, jjj, jbb
  - BumpHunter is used to measure local excess using dijet mass distribution

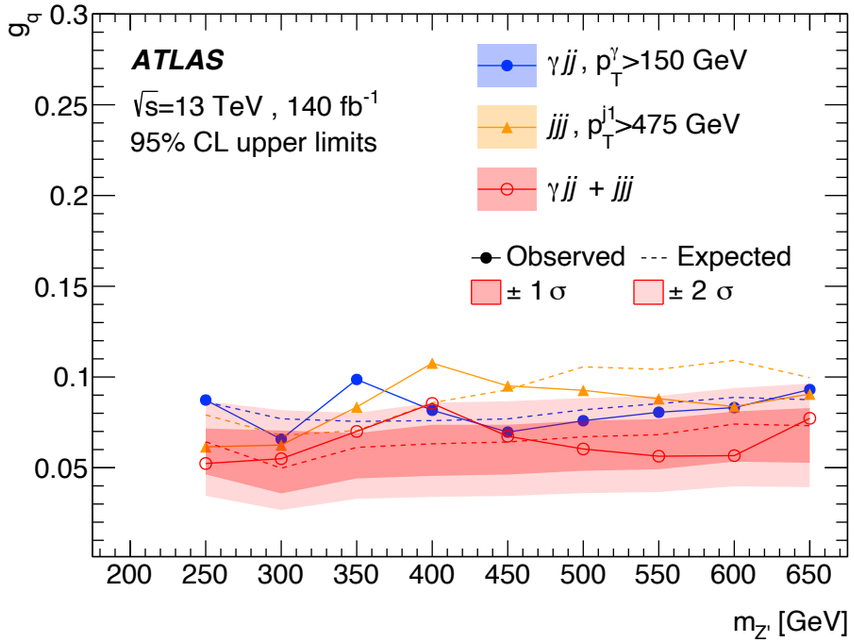


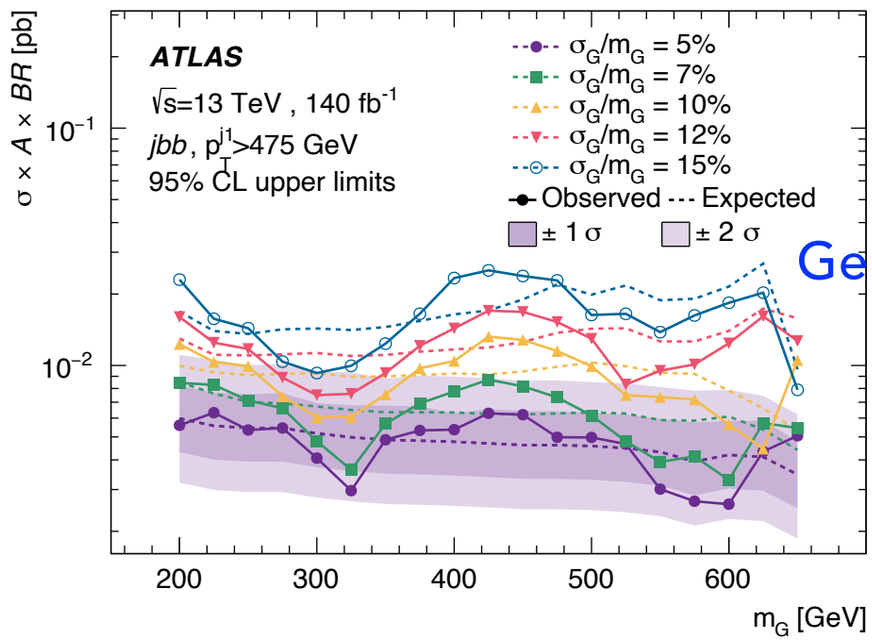


Results









Generic BSM

- No significant local excess observed, exclusion limits obtained.
- 50% enhancement on Z'- q-q coupling g_q limits from previous results.
- Most stringent g_q limits: jjj channel for lower Z', γjj channel for higher Z' masses; combined jjj and γjj channels achieve g_q limit down to 0.05-0.07.