

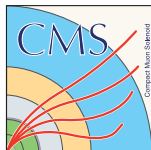
Recent Results from ATLAS and CMS Searches for Dark Matter

Harish Potti on behalf of the ATLAS and CMS collaborations

The University of Sydney

31st August 2026

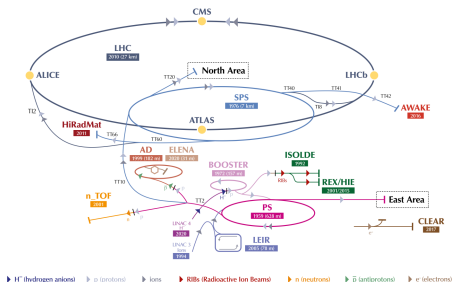
PPC 2026, UNSW Sydney, Australia



THE LARGE HADRON COLLIDER

- ▶ The Large Hadron Collider (LHC) is a circular particle accelerator
- ▶ High-energy proton beams are made to collide at E_{CM} up to 13.6 TeV

The CERN accelerator complex
Complexe des accélérateurs du CERN

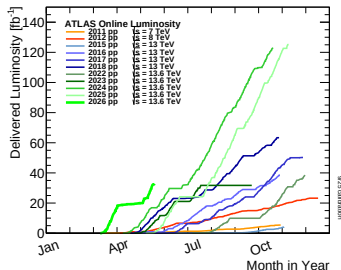
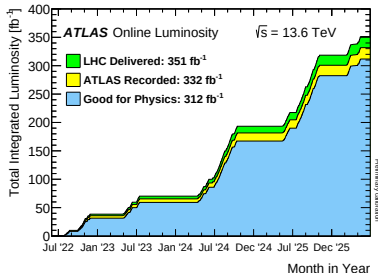


- ▶ 27 km in circumference and located 100 m beneath the surface
- ▶ Two general purpose detectors: ATLAS and CMS
- ▶ Two specialized detectors: LHCb and ALICE
- ▶ Superconducting coils are used to provide a magnetic field of up to 8.3 T

LHC - Large Hadron Collider // SPS - Super Proton Synchrotron // PS - Proton Synchrotron // AD - Antiproton Decelerator // CLEAR - CERN Linear Electron Accelerator for Research // AWAKE - Advanced WAKEfield Experiment // ISOLDE - Isotope Separator OnLine // REX/HIE - Radioactive Experiment/High Intensity and Energy ISOLDE // LEIR - Low Energy Ion Ring // UNAC - UNear ACcelerator // n_TOF - Neutrons Time Of Flight // HIRadMat - High-Radiation to Materials

LHC STATUS

- ▶ During Run-2 data taking period (2015-18), the LHC has delivered $\sim 156 \text{ fb}^{-1}$ of pp collision data at $\sqrt{s} = 13 \text{ TeV}$
- ▶ The LHC has delivered 351 fb^{-1} at $\sqrt{s} = 13.6 \text{ TeV}$ during Run-3 data taking period (2022-26)
- ▶ Analyzing diverse dark matter models using full Run-2 and Run-3 data opens exciting new avenues to extend experimental reach into uncharted dark sector regions

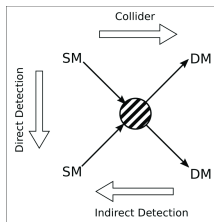


DARK MATTER: INTRODUCTION

- ▶ Compelling evidence for the existence of dark matter (DM) from Astrophysical and cosmological observations
- ▶ DM is not described by the Standard Model of Particle Physics (SM)
- ▶ The nature of DM and its possible interactions with SM particles remains unknown despite its dominant contribution to the total matter density
- ▶ To date, its presence has been inferred only through its gravitational effects. No conclusive evidence for nongravitational interactions so far

DARK MATTER: INTRODUCTION - 2

- ▶ Many extensions of the SM predict that DM may consist of stable or long-lived particles that could be produced directly in high-energy collisions at the LHC.
- ▶ If such particles interact weakly with the detector, the resulting event will have a large imbalance in the transverse momentum (p_T^{miss})
- ▶ When these DM particles recoil against energetic visible objects, such as jets, photons, the resulting topology can be exploited to search for DM signatures.



OUTLINE

In this talk, I will highlight a few selected results from the ATLAS and CMS dark matter search program.

CMS: Monojet + MET

ATLAS: Forward Dilepton + Missing Mass

CMS: Inert Doublet Model

ATLAS: Top squark pair production

CMS: Mono-Higgs ($b\bar{b}$) + MET

ATLAS: DM Summary plots (s -channel & dark Higgs)

CMS: Dark Higgs + MET

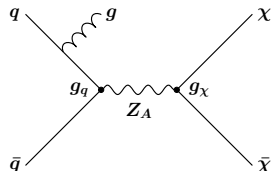
ATLAS: Low-Mass dijet in pileup

CMS SEARCH FOR MONOJET + MET

- New Run-3 CMS result with 13.6 TeV data collected in 2022 & 2023 (62 fb^{-1})

Interpretations in multiple theoretical contexts:

- Invisible Higgs boson decays
- Simplified DM models
 - spin-1 mediators (vector and axial-vector)
 - spin-0 mediators (scalar and pseudoscalar)
- Models with large extra spatial dimensions



One or more energetic jets
+ large p_T^{miss}

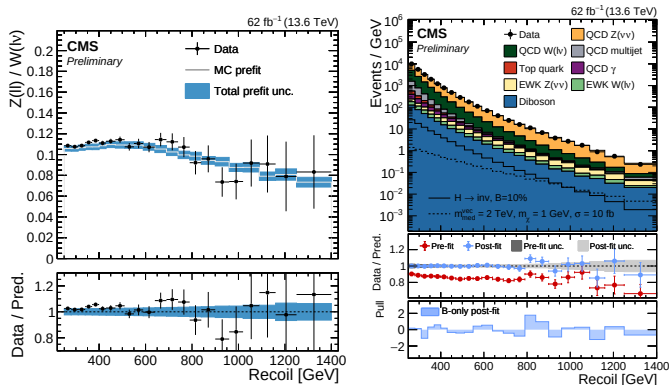
CMS-PAS-NPS-25-008

MONOJET + MET: ANALYSIS STRATEGY

SR selection: $p_T^j > 100$ GeV, $E_T^{\text{miss}} > 250$ GeV, $\min \Delta\phi(j, E_T^{\text{miss}}) > 0.5$,
Lepton/photon/b-jet veto

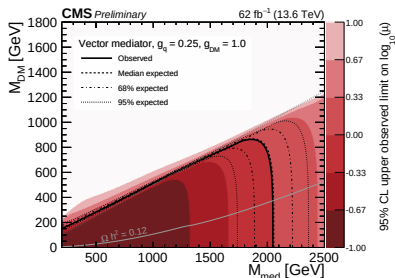
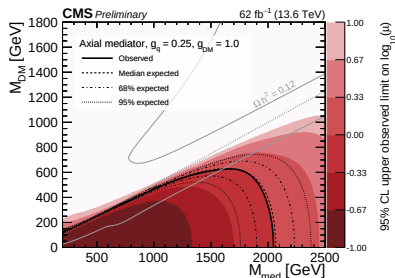
Fit strategy:

- ▶ $1e$ and 1μ CRs constrain W +jets
- ▶ $2e$, 2μ , and 1γ CRs constrain $Z(\nu\nu)$ +jets
- ▶ simultaneous binned fit of the SR and five CRs
- ▶ Hadronic recoil in the SR and CRs are used for the fit

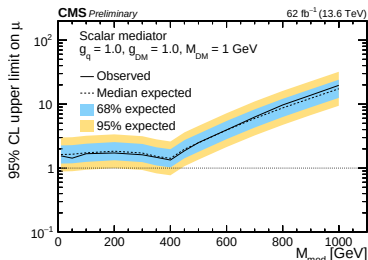


MONOJET + MET: RESULTS-1

- ▶ No evidence for a significant excess
- ▶ Vector and axial-vector mediator masses of up to about 2 TeV are excluded for light DM
- ▶ Observed (expected) 95% CL upper limit on $\mathcal{B}(H \rightarrow \text{inv}) = 42\%$ (39%)
- ▶ Pseudoscalar mediator masses below about 450 GeV are excluded for $g_q = g_{\text{DM}} = 1.0$ and $M_{\text{DM}} = 1$ GeV



MONOJET + MET: RESULTS-2

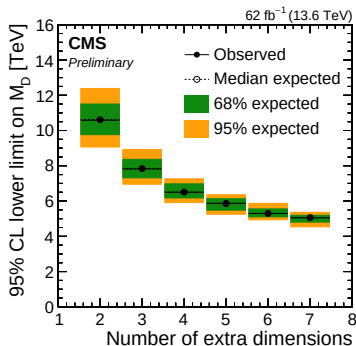


At 95% CL, CMS set lower limits:

$$M_D > 10.6 \text{ TeV } (d = 2)$$

decreasing to,

$$M_D > 5.1 \text{ TeV } (d = 7)$$



OUTLINE

CMS: Monojet + MET

ATLAS: Forward Dilepton + Missing Mass

CMS: Inert Doublet Model

ATLAS: Top squark pair production

CMS: Mono-Higgs ($b\bar{b}$) + MET

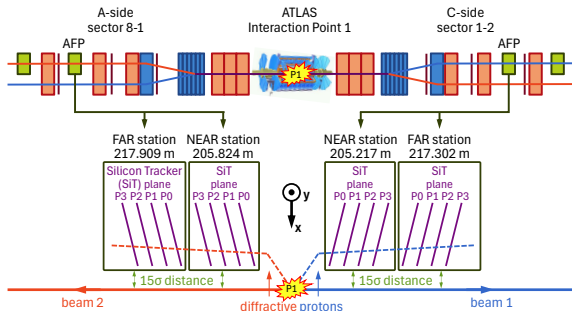
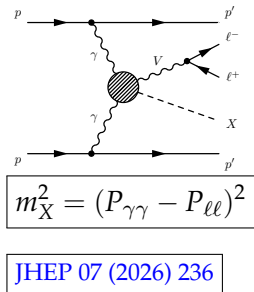
ATLAS: DM Summary plots (s -channel & dark Higgs)

CMS: Dark Higgs + MET

ATLAS: Low-Mass dijet in pileup

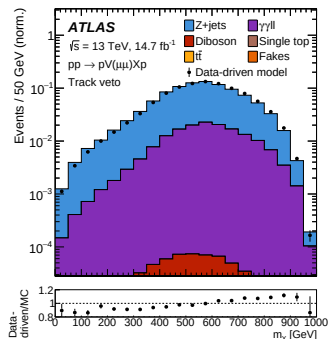
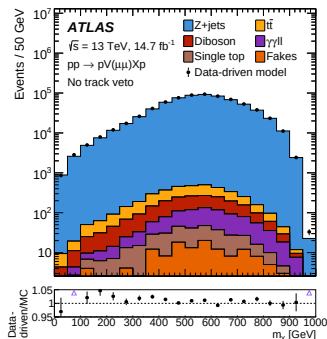
MISSING-MASS SEARCH IN FORWARD-PROTON-TAGGED DILEPTON EVENTS

- ▶ Forward proton tagging offers model-independent reconstruction of invisible mass; full kinematic info from $\gamma\gamma \rightarrow$ ATLAS forward proton (AFP) spectrometer
- ▶ Signature: Missing energy when measuring outgoing proton energies in AFP, assuming pp as a coherent source of photons at low Q^2 (protons remain intact)



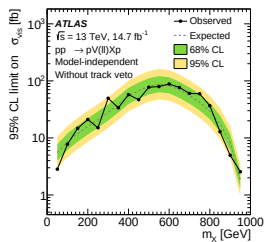
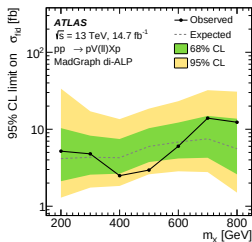
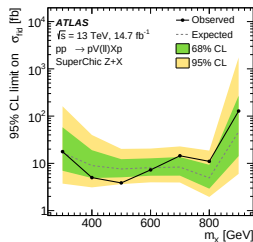
FORWARD DILEPTON + MISSING MASS

- ▶ Missing mass m_X reconstructed by kinematic subtraction of central leptons from forward proton energy loss ΔE_p
- ▶ Analysis uses 2017 data tagged by the AFP spectrometer
- ▶ **Selection:** OSSF leptons ($p_T^e > 18$ GeV, $p_T^\mu > 15$ GeV), $m_{\ell\ell} > 50$ GeV, $p_T^{\ell\ell} > 20$ GeV, $0.035 < \xi_p < 0.08$
- ▶ **Track Veto:** Requires zero additional ID tracks near the dilepton vertex to suppress Z + jets combinatorial pile-up background.



FORWARD DILEPTON + MISSING MASS: RESULTS

- ▶ No significant excess over SM observed in the missing-mass spectrum $[100, 900]$ GeV
- ▶ **Model-Dependent Limits:** 95% CL Upper limits set on fiducial cross sections across simplified models ($Z + X$, $Z + H'$, di-ALP) in $[4.0 \text{ pb}, 5.3 \text{ fb}]$.
- ▶ **Model-Independent Limits:** Model-agnostic limits on visible BSM xsec set for two sets of selection criteria.



OUTLINE

CMS: Monojet + MET

ATLAS: Forward Dilepton + Missing Mass

CMS: Inert Doublet Model

ATLAS: Top squark pair production

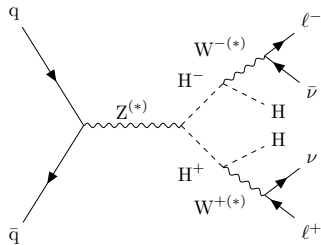
CMS: Mono-Higgs ($b\bar{b}$) + MET

ATLAS: DM Summary plots (s -channel & dark Higgs)

CMS: Dark Higgs + MET

ATLAS: Low-Mass dijet in pileup

SEARCH FOR INERT DOUBLET MODEL (IDM) NEUTRAL SCALARS



Dilepton + E_T^{miss} with a
stable H as dark matter
candidate

[arXiv:2605.13614](https://arxiv.org/abs/2605.13614)

(submitted to JHEP)

- ▶ Second higgs doublet: four additional scalar bosons ($H, A, H^\pm$) are predicted
- ▶ Through an additional discrete symmetry, the lightest new scalar, H , is stable (DM candidate)
- ▶ Electroweak production of new inert scalars
- ▶ **First dedicated CMS search for the Inert Doublet Model**

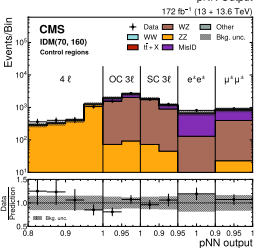
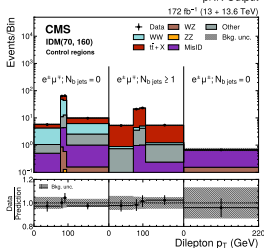
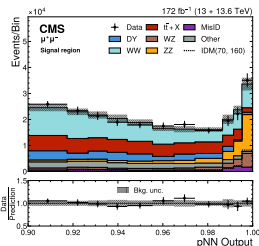
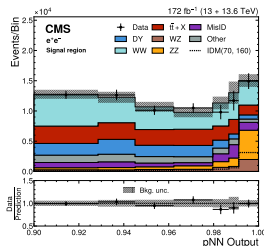
INERT DOUBLET MODEL: ANALYSIS STRATEGY

Selection cuts:

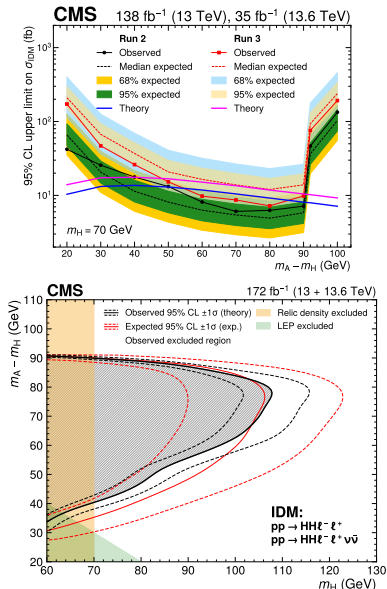
- ▶ ee or $\mu\mu$, opposite sign (OSSF pair) with a veto on additional lepton
- ▶ ≤ 1 jet and 0 b-jets

Parameterised NN:

- ▶ (m_H, m_A) as inputs;
one NN covers
complete mass plane
- ▶ 26 kinematic input
variables
- ▶ Signal region defined
by: $pNN > 0.9$
- ▶ pNN output used as
final discriminant



INERT DOUBLET MODEL: RESULTS



- The observed (expected) exclusion region reaches $m_H = 108$ (106) GeV for $m_A - m_H = 78$ (76) GeV
- **First limits on the masses of the neutral scalars in the IDM obtained by a dedicated search**

OUTLINE

CMS: Monojet + MET

ATLAS: Forward Dilepton + Missing Mass

CMS: Inert Doublet Model

ATLAS: Top squark pair production

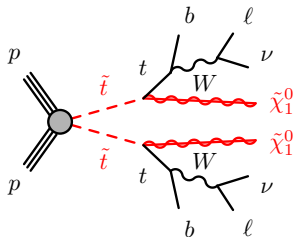
CMS: Mono-Higgs ($b\bar{b}$) + MET

ATLAS: DM Summary plots (s -channel & dark Higgs)

CMS: Dark Higgs + MET

ATLAS: Low-Mass dijet in pileup

TOP SQUARK PAIR PRODUCTION IN DILEPTON CHANNEL



Run-2 + early Run-3
data

[arXiv: 2603.16191](https://arxiv.org/abs/2603.16191)
(submitted to JHEP)

- The naturalness of the Higgs boson mass requires a top squark with mass around the TeV scale $\Rightarrow$ good candidate for discovery at the LHC!
- The lightest neutralino ($\tilde{\chi}_1^0$) is assumed to be the lightest supersymmetric particle & a viable DM candidate
- Simplified model:
 - $\mathcal{B}(\tilde{t} \rightarrow t \tilde{\chi}_1^0) = 100\%$
 - Parameters: $m(\tilde{t}_1), m(\tilde{\chi}_1^0)$

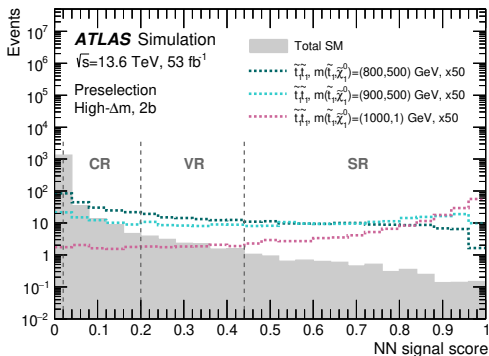
ANALYSIS STRATEGY

Six Neural Networks (NNs) are trained to discriminate between signal and background, optimised using signals with different mass splittings

$\Delta m(t_1, \tilde{\chi}_1^0)$:

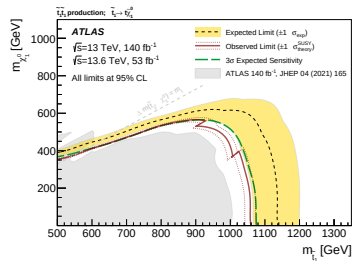
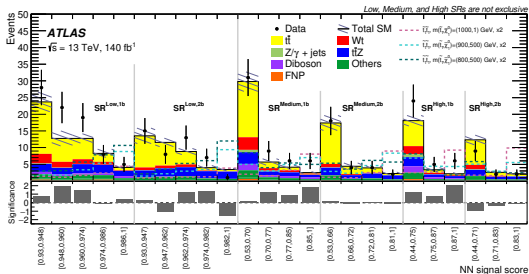
- ▶ low mass Δm : 200 - 300 GeV
- ▶ medium Δm : 300 - 500 GeV
- ▶ high Δm : ≥ 600 GeV

- ▶ Main backgrounds ($t\bar{t}$, $t\bar{t}Z$) are normalised CRs
- ▶ Analysis regions are defined based on the NN scores



TOP SQUARK PAIR PRODUCTION IN DILEPTON CHANNEL: RESULTS

- ▶ No significant excess over SM expectation
- ▶ 95% CL exclusion limits set in the $m(\tilde{t}_1) - m(\tilde{\chi}_1^0)$ plane
- ▶ Extends the previous ATLAS limits by $\sim 10\%$ in mass reach
- ▶ For a benchmark signal (1 TeV $\tilde{t}_1$, 400 GeV $\tilde{\chi}_1^0$), the upper limit on the signal strength improved by 50% from the improved reconstruction and new analysis strategy. A further 20% improvement due to the addition of Run 3 data.



OUTLINE

CMS: Monojet + MET

ATLAS: Forward Dilepton + Missing Mass

CMS: Inert Doublet Model

ATLAS: Top squark pair production

CMS: Mono-Higgs ($b\bar{b}$) + MET

ATLAS: DM Summary plots (s -channel & dark Higgs)

CMS: Dark Higgs + MET

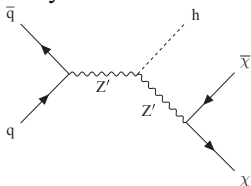
ATLAS: Low-Mass dijet in pileup

MONO-HIGGS ($b\bar{b}$) + MET

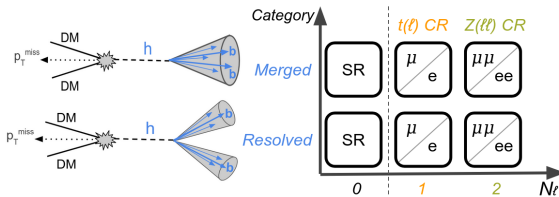
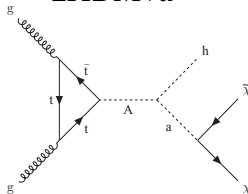
- Search for dark matter produced in association with a SM Higgs boson, which decays as $h \rightarrow b\bar{b}$

Phys. Rev. D 113, 092016

baryonic Z' model

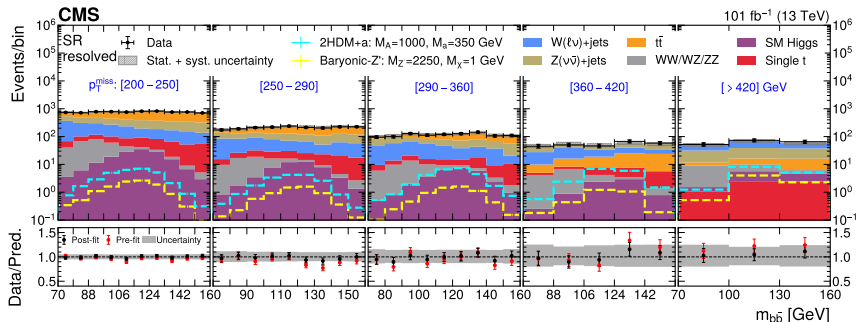


2HDM+a



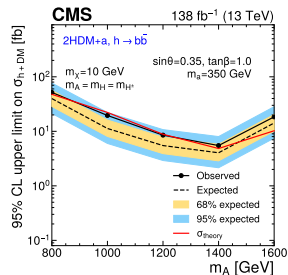
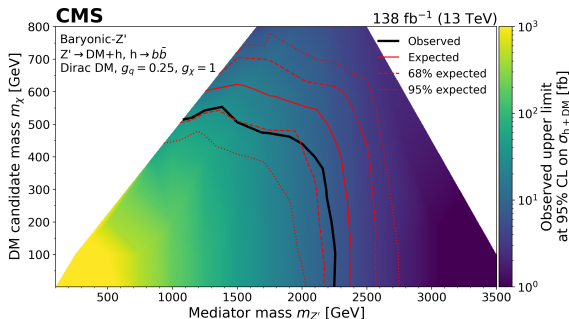
MONO-HIGGS ($b\bar{b}$) + MET: BACKGROUND ESTIMATION

- ▶ $Z(\nu\nu)$ +jets: constrained with $Z \rightarrow ee/\mu\mu$ control regions
- ▶ $t\bar{t}(1\ell)$: constrained with top-enriched e/μ regions
- ▶ W +jets, single top, diboson and SM Higgs processes taken from simulation
- ▶ Simultaneous likelihood fit of all signal and control regions



MONO-HIGGS ($b\bar{b}$) + MET: RESULTS

- The observed data agree with the SM background predictions
- Baryonic- Z' : $m_{Z'} > 2.25$ TeV ($m_\chi = 1$ GeV)
- 2HDM+a: $m_A \notin (850, 1300)$ GeV ($m_a = 350$ GeV)
- Strongest limits for the mono-Higgs analysis



OUTLINE

CMS: Monojet + MET

ATLAS: Forward Dilepton + Missing Mass

CMS: Inert Doublet Model

ATLAS: Top squark pair production

CMS: Mono-Higgs ($b\bar{b}$) + MET

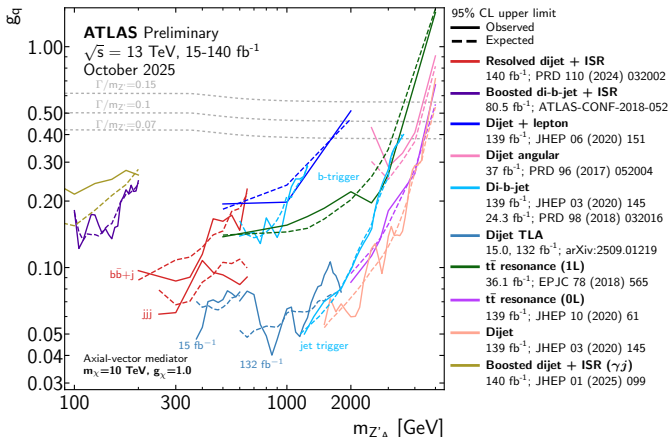
ATLAS: DM Summary plots (s -channel & dark Higgs)

CMS: Dark Higgs + MET

ATLAS: Low-Mass dijet in pileup

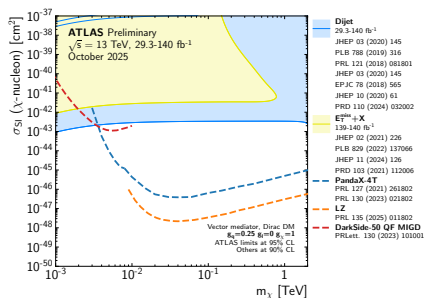
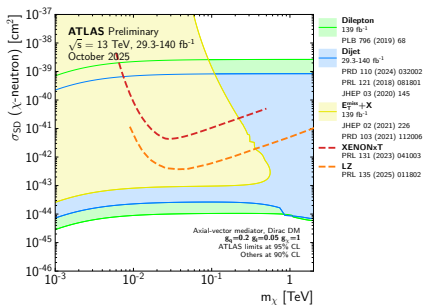
DM SUMMARY PLOTS: s -CHANNEL & DARK HIGGS

- ▶ Visible resonance searches and E_T^{miss} searches cover complementary regions of the spin-1 mediator parameter space
- ▶ m_χ is set to 10 TeV to prevent the mediator from decaying into DM
- ▶ [ATL-PHYS-PUB-2025-041](#)



ATLAS DARK MATTER SUMMARY PLOTS FOR s-CHANNEL AND DARK HIGGS MODELS

- ATLAS leading sensitivity for spin-dependent scenarios, while direct detection experiments lead sensitivity for spin-independent scenarios at high DM mass range.



OUTLINE

CMS: Monojet + MET

ATLAS: Forward Dilepton + Missing Mass

CMS: Inert Doublet Model

ATLAS: Top squark pair production

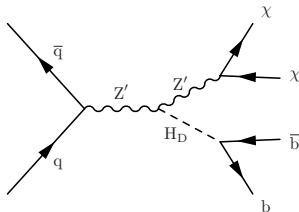
CMS: Mono-Higgs ($b\bar{b}$) + MET

ATLAS: DM Summary plots (s -channel & dark Higgs)

CMS: Dark Higgs + MET

ATLAS: Low-Mass dijet in pileup

CMS SEARCH FOR DARK HIGGS



[arXiv:2604.20999](https://arxiv.org/abs/2604.20999)

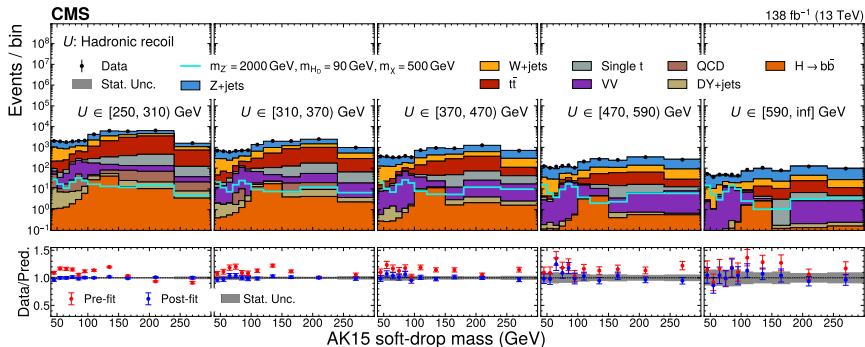
(submitted to EPJC)

- Dark-sector search with $H_D \rightarrow b\bar{b}$ and large MET
- Targets the low-mass region:
 $50 \leq m_H \leq 150$ GeV, below the WW threshold
- Only scenarios in which the DM particle is more massive than the H_D boson are considered.

CMS DARK HIGGS: ANALYSIS STRATEGY

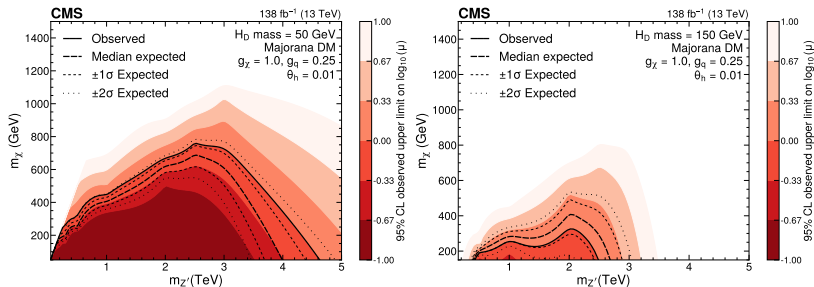
Event selection:

- ▶ One H_D candidate, which is an AK15 jet with $p_T > 160$ GeV, $|\eta| < 2.4$, and soft drop mass m_{SD} in the $[40, 300]$ GeV range
- ▶ hadronic recoil $U > 250$ GeV.
- ▶ Veto events with isolated leptons or photons or additional b-jets
- ▶ Major bkg (Z +jets, W +jets, $t\bar{t}$) are estimated using CRs



CMS DARK HIGGS: RESULTS

- ▶ No significant excess is observed above the background
- ▶ Mediator masses up to 4.5 (2.5) TeV are excluded for an H_D boson of 50 (150) GeV
- ▶ **These are the most stringent limits set for the dark Higgs boson masses to date**



OUTLINE

CMS: Monojet + MET

ATLAS: Forward Dilepton + Missing Mass

CMS: Inert Doublet Model

ATLAS: Top squark pair production

CMS: Mono-Higgs ($b\bar{b}$) + MET

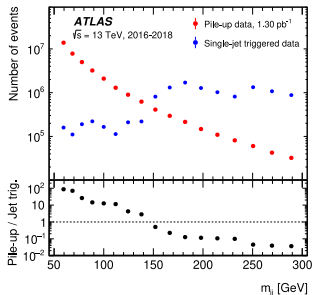
ATLAS: DM Summary plots (s -channel & dark Higgs)

CMS: Dark Higgs + MET

ATLAS: Low-Mass dijet in pileup

ATLAS SEARCH FOR LOW-MASS DIJET RESONANCES IN PILEUP COLLISIONS

- ▶ Access to the low end of the di-jet mass spectrum can be gained by looking at jets into pileup vertices excluding the hard-scattering vertex.
- ▶ Search for low mass dijet resonances in pile-up collisions for the first time
- ▶ Trigger unbiased dataset which is not affected by jet trigger prescales at low energies
- ▶ This mass range previously only accessible for boosted searches with triggering on ISR energies



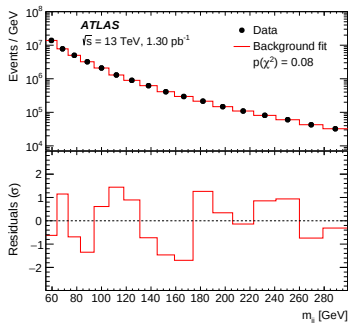
[arXiv:2606.03222](https://arxiv.org/abs/2606.03222)
(submitted to EPJC)

Search for decays into two jets:

- ▶ Simplified Z' axial-vector mediator with coupling to quarks
- ▶ Generic Gaussian shaped resonances

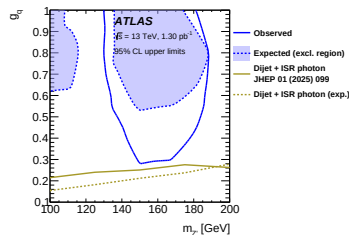
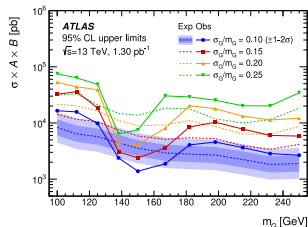
LOW-MASS DIJET RESONANCES IN PILEUP COLLISIONS

- ▶ **Selection:** $p_T > 17$ GeV, $|\eta| < 2.0$ and rapidity difference $|y^*| < 0.8$
- ▶ Data-driven background estimate as simulation not feasible due to large statistics
- ▶ Parametrized using a 5-parameter dijet function combined with a sigmoid turn-on modeling the $p_T > 17$ GeV threshold effect
- ▶ Search for BSM resonances above 100 GeV, as overlap with W/Z makes separating signal challenging



LOW-MASS DIJET RESONANCES IN PILEUP COLLISIONS: RESULTS

- ▶ Z' DM Mediator Limits (95% CL):
Excludes masses 135–185 GeV for $g_q = 0.6$; lowest excluded quark coupling $g_q = 0.28$ at $m_{Z'} = 150$ GeV.
- ▶ Unique sensitivity to models that couple preferentially with gluons
 - ▶ Boosted dijet + ISR photon search restricted to initial states with quarks
 - ▶ Boosted di-b-jet + ISR jet search restricted to b-tagged final states
- ▶ **Lowest resolved dijet mass studied at the LHC**



CONCLUSIONS

- ▶ Comprehensive dark matter search program at both ATLAS and CMS
- ▶ A diverse range of DM scenarios are probed with Run-2 and Run-3 datasets, pushing sensitivity into unexplored dark sector territory
 - ▶ electroweak scalars
 - ▶ higgs portals
 - ▶ mono-object final states
 - ▶ di-jet searches etc.
- ▶ Many more exciting measurements can be found here:
 - ▶ ATLAS: <https://twiki.cern.ch/twiki/bin/view/AtlasPublic/>
 - ▶ CMS: <https://twiki.cern.ch/twiki/bin/view/CMSPublic/>
- ▶ No excess YET but the ongoing full Run-3 dataset ($\sim 300 \text{ fb}^{-1}$) presents exciting opportunities. So, stay tuned for future results!!

Thank You