Tamara Vázquez Schröder (IFAE)

on behalf of the ATLAS and CMS Collaborations

EPS-HEP conference 11 July 2025 - Marseille, France













The Standard Model of Particle Physics

No gravity!

No verified theory of quantum gravity

No neutrino masses!

Are they Dirac or Majorana particles?

No naturalness!

Higgs field parameters seem highly fine-tuned

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But needed to explain astrophysical observations

The universe is in accelerated expansion invisible source of energy?

Not enough matterantimatter asymmetry!

To explain dominance of matter today

No dark matter!

No dark energy!

Why 3 fermion generations?

Underlying symmetry connecting quark and lepton sectors?

Why hierarchical Yukawa coupling?

Why is the top quark so heavy?



Exploring all extensions of the SM

The sea of beyond the SM theories is vast and difficult to cover in 30 min

Dark Sector

<Insert model here>

Supersymmetry

<Insert model here>

Leptoquarks

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Vector-like fermions

Two-Higgs-Doublet models

<Insert model here>

<Insert model here>

Quantum Black Holes



Exploring all extensions of the SM

- The sea of beyond the SM theories is vast and difficult to cover in 30 min
- Focus only on **brand-new results** released for this conference
- models and signatures in the detector

Dark Sector

<Insert model here>

Supersymmetry

<Insert model here>

Vector-like fermions

Leptoquarks

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special edition

New Run-3 results, accessing new corners of the phase-space, improving tagger performances, explore new

Two-Higgs-Doublet models

<Insert model here>

<Insert model here>

Quantum Black Holes



more than just a laundry list



more than just a laundry list

display the latest searches to unveil BSM physics





Heavy fermions & **lq-coupled bosons**

Vector-like quarks

- Hypothetical spin-¹/₂ coloured particles
- LH and RH components transform the same way under SM gauge group
- Mass not from Yukawas, evade Higgs constraints on 4th gen quarks

vector-like quarks leptoquarks

Leptoquarks

- Colour triplet bosons with fractional electric charge
- Carry both lepton and baryon number
- Can enable violation of lepton flavour universality





VLQ: $T/Y \rightarrow Wb(1\ell)$

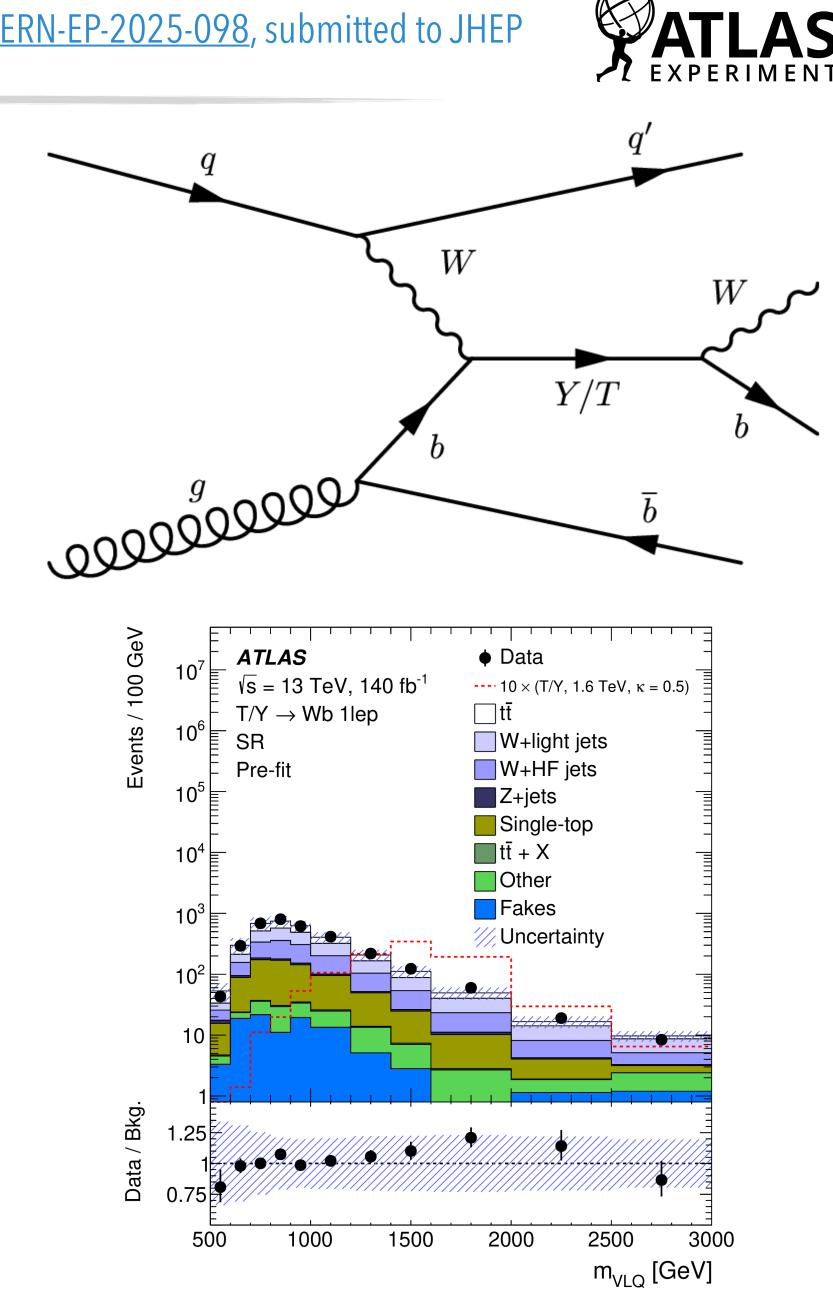
- Search for singlet-**T** with BR (Wb:Zt:Ht) = $(\frac{1}{2}:\frac{1}{4}:\frac{1}{4})$ and **Y** in a (T, B, Y) triplet (100% decay to Wb)
 - Focus on **Wb** decay mode, with coupling-strength parameter κ
- Single lepton channel (from W leptonic decay)
- Main backgrounds: $t\bar{t} + single top, W+jets$

• Single top SM diagrams can interfere with signal (singlet-T, triplet-Y)

- Dealt with by matrix-element level reweighting
- Statistical model: $\mu \times S + \sqrt{\mu} \times I + B$
- SR, tt CR and W+jets CR each split in 3 bins of p_T^W
 - Better control on some systematics (e.g. W+jets modelling) and overall better sensitivity than merged
 - Fit m_{VLQ} discriminant

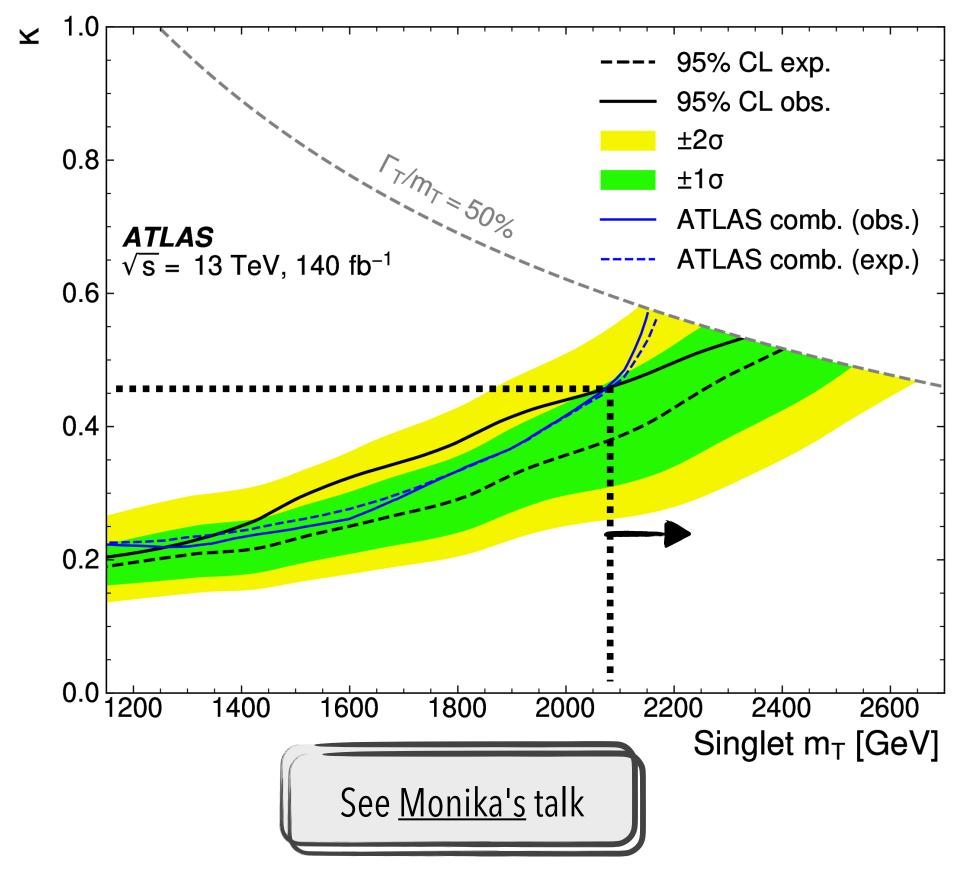
<u>CERN-EP-2025-098</u>, submitted to JHEP





$\bigvee LQ: T/Y \rightarrow Wb(1\ell)$

limits on Y in most of the phase space (JHEP 02 (2025) 075)

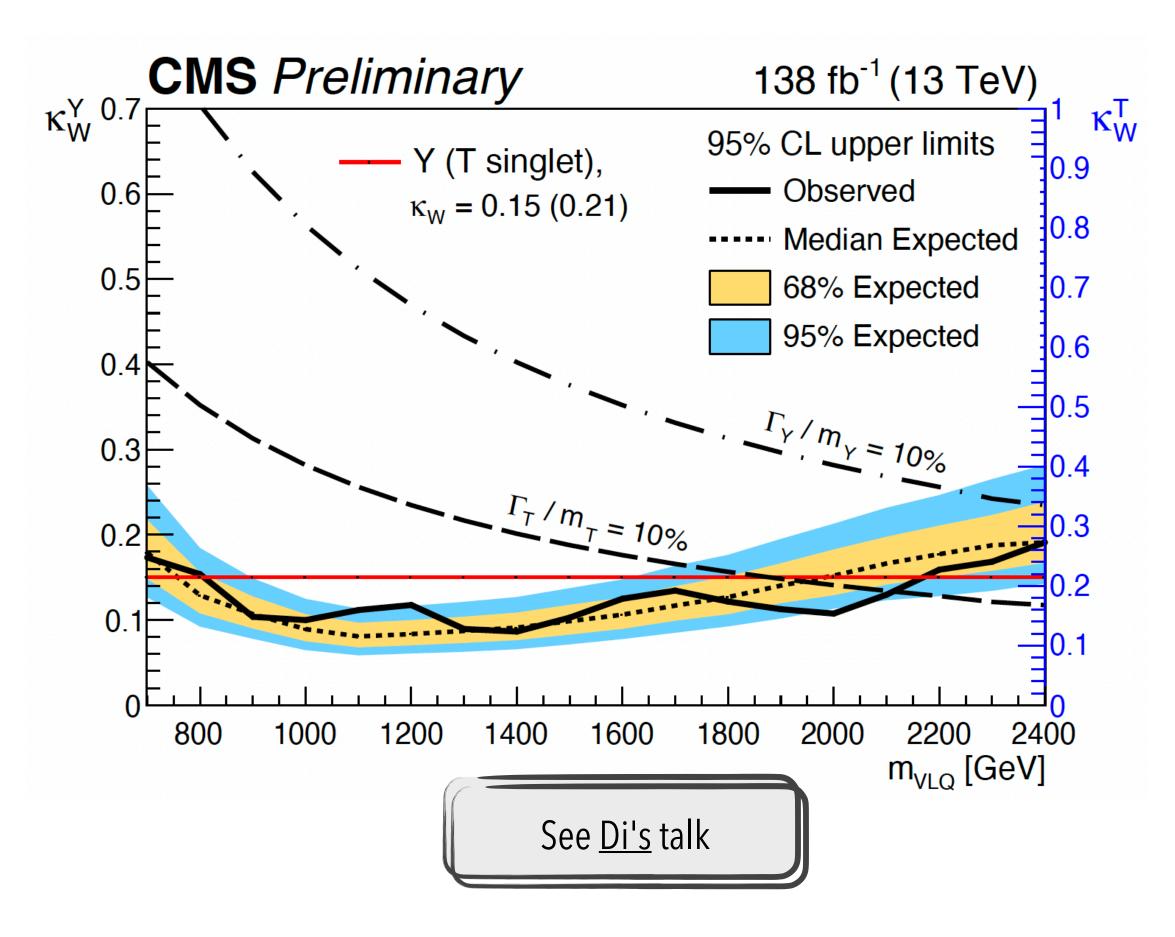


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CMS-PAS-B2G-22-004

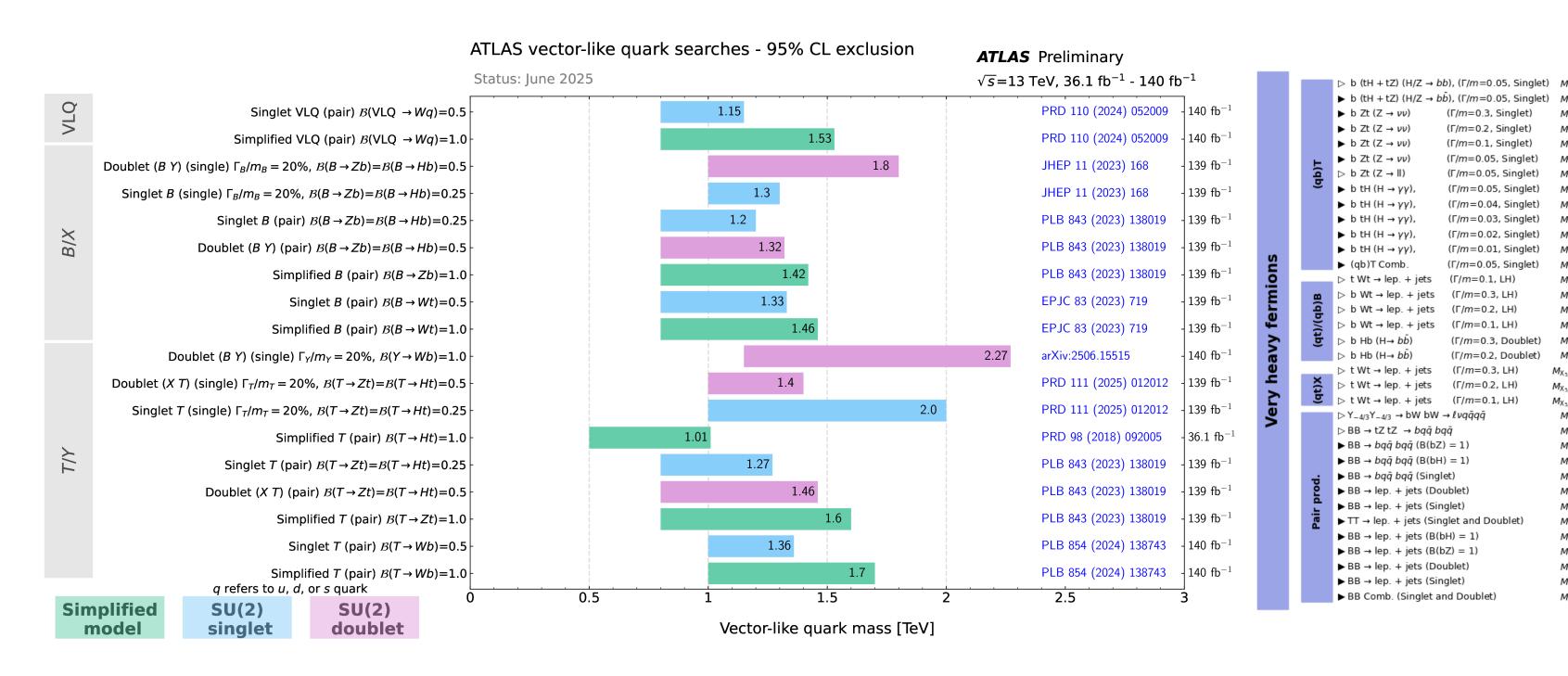
This search extends the limit above $m_T \sim 2100$ GeV wrt. previous ATLAS combination (PRD 111) (2025) 012012), whereas ATLAS search in the fully-hadronic channel remains with more stringent













CMS summary (2024)



Overview of CMS B2G Results

(F/m=0.3, Singlet)

(Γ/m=0.2, Singlet)

(F/m=0.1, Singlet)

(F/m=0.05, Singlet)

(Γ/m=0.05, Singlet)

(Γ/m=0.05, Singlet)

(F/m=0.04, Singlet)

(F/m=0.03, Singlet)

(F/m=0.02, Singlet)

(F/m=0.01, Singlet)

([[]/m=0.05, Singlet)

(Γ/m=0.1, LH)

(Γ/m=0.3, LH)

(Γ/m=0.2, LH)

(Γ/m=0.1, LH)

(Γ/m=0.3, LH)

(Γ/m=0.2, LH)

(Γ/m=0.1, LH)

(F/m=0.3, Doublet)

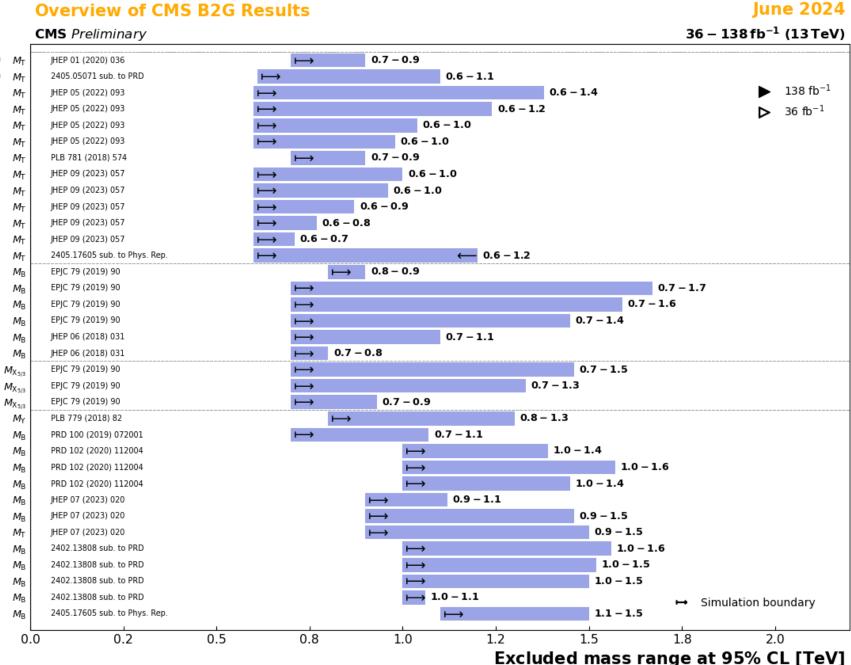
(Γ/m=0.2, Doublet)

M

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jets

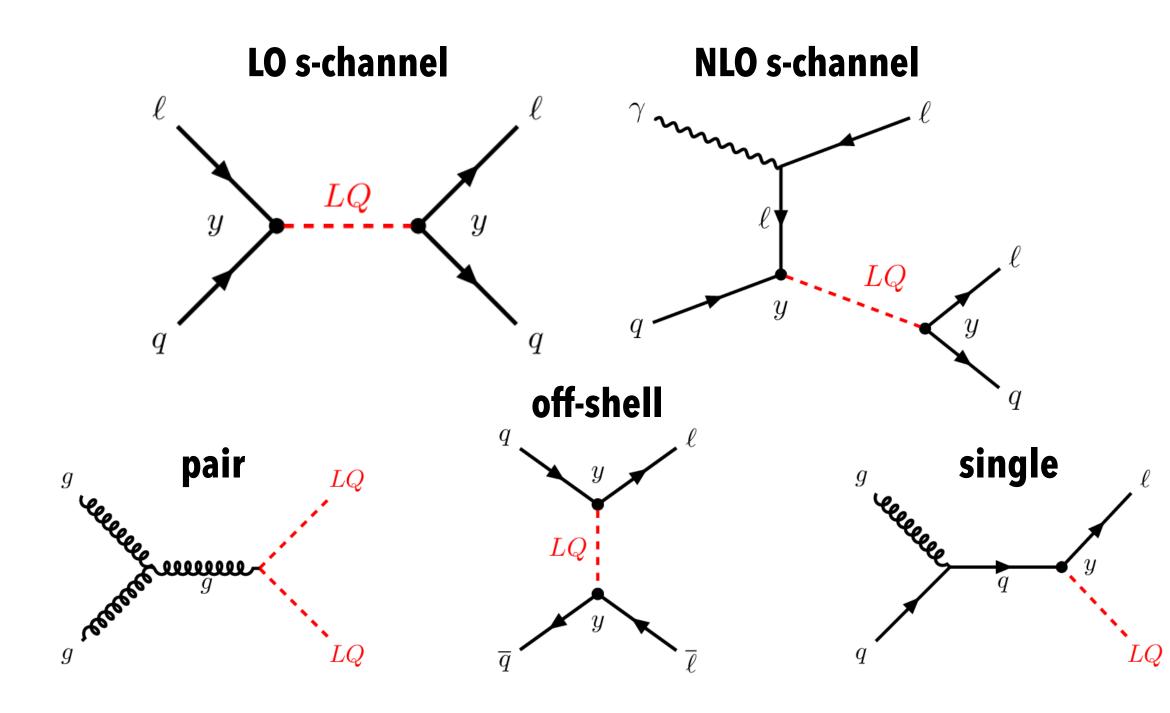






Resonant s-channel LQ

- First ATLAS search for resonant, s-channel prod. of LQs via lepton PDFs, LQ decay to 1 lepton + 1 jet
- "NLO" contributions via photon PDF motivate also targeting 2-lepton (+jet) final states
 - Common to t-channel and single LQ production as well

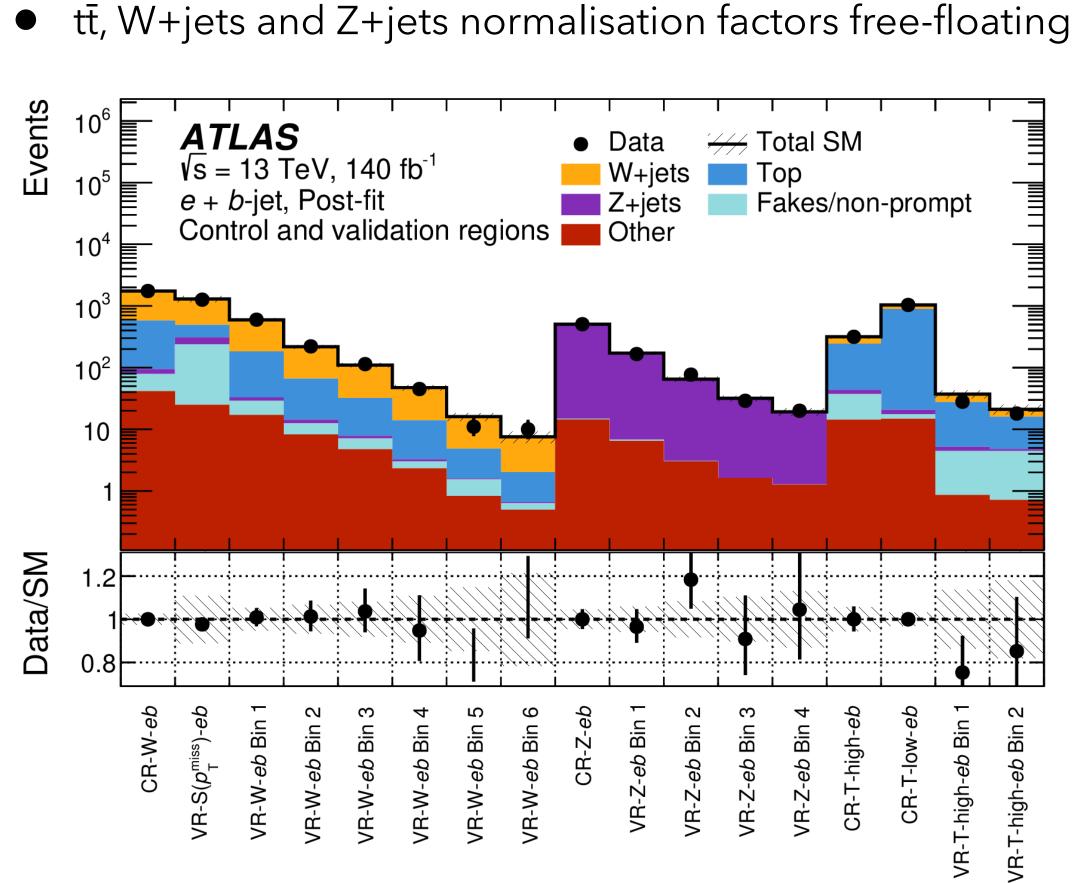


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CERN-EP-2025-142, submitted to JHEP



- Final states: e+light-jet, μ +light-jet, e+b-jet, μ +b-jet
- Using Run 2 (140 fb⁻¹) + partial Run 3 (55 fb⁻¹) datasets
- Fit m_{li} distributions

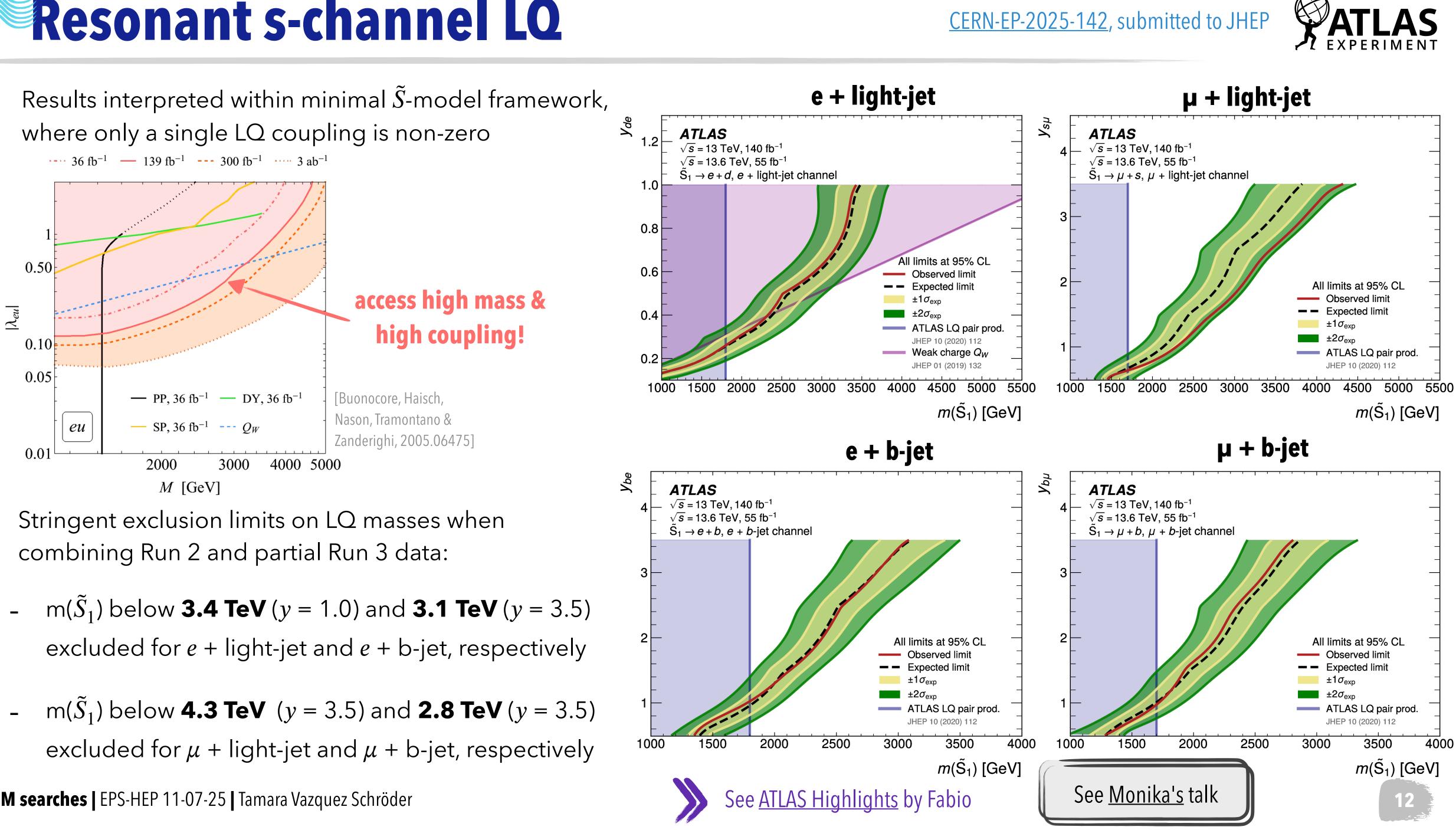






Resonant s-channel LQ

Results interpreted within minimal \tilde{S} -model framework,



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Supersymmetry

- A superpartner for every SM particle
- Fermion superpartners of the Higgs and weak gauge bosons can be WIMP dark matter
- Gauge couplings unify at a single GUT scale
- Elegant solution to the hierarchy problem

squarks & sgluinos **RPV SUSY 1**² + multi-(b)jets stop / bino-wino annihilation LLP

- R-parity-conserving (RPC): superpartners are pairproduced and Lightest Supersymmetric Particle (LSP) is stable $\rightarrow E_T^{miss}$ in the final state
- R-parity-violating (RPV): the LSP is allowed to decay into SM particles, voiding the E_T^{miss} signature

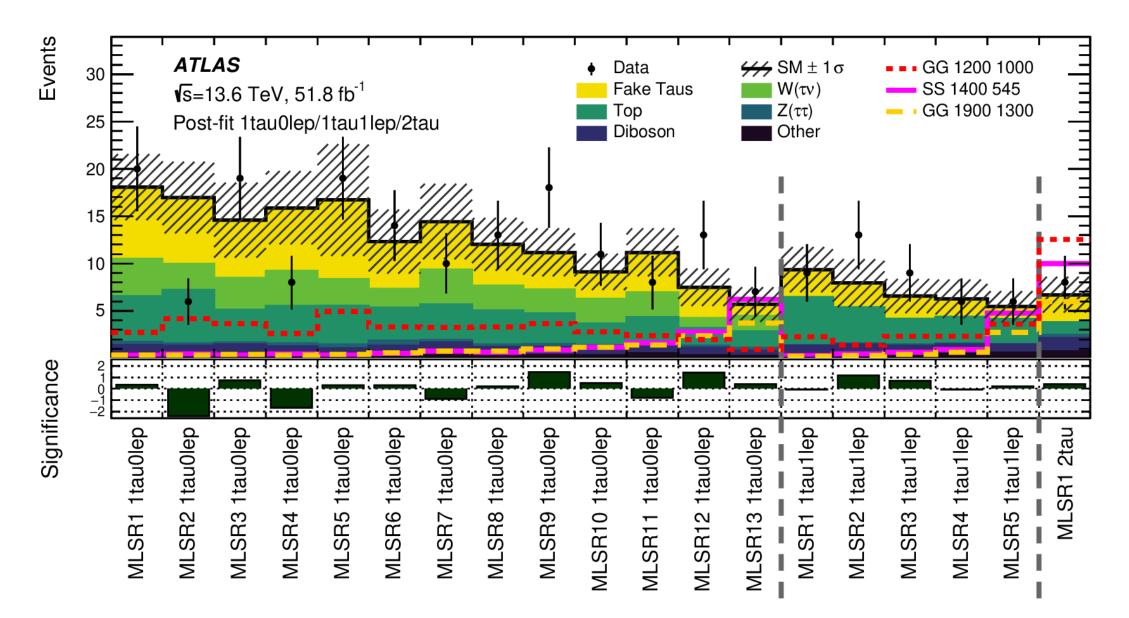


RPC squarks & gluinos: τ+E_Tmiss

- Search for strongly pair produced squarks and gluinos decaying to τ , jets and E_T^{miss}
- Common cascade decay in MSSM
- Using Run 2 (140 fb⁻¹) + partial Run 3 (51.8 fb⁻¹) datasets
- Event selected with E_T^{miss} triggers

• Machine-Learning based:

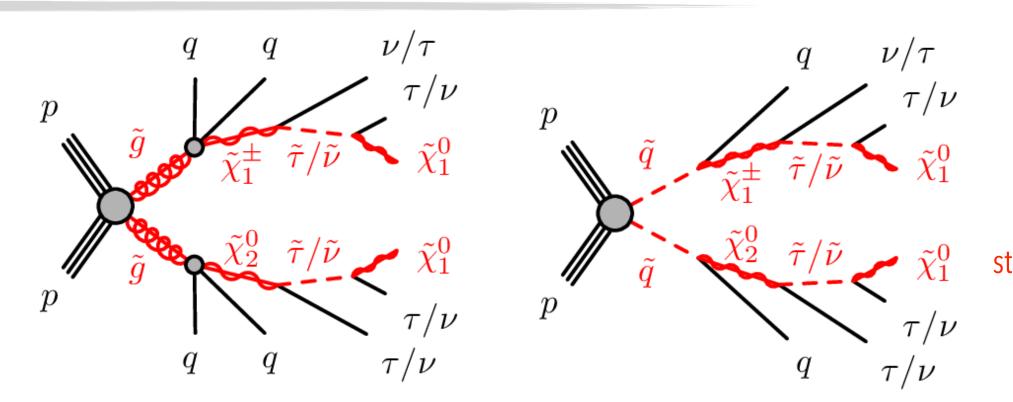
- Regions defined with **multiclass-classifier**
- Channels: $1\tau 0\ell$, $1\tau 1\ell$, $2\tau 0\ell$



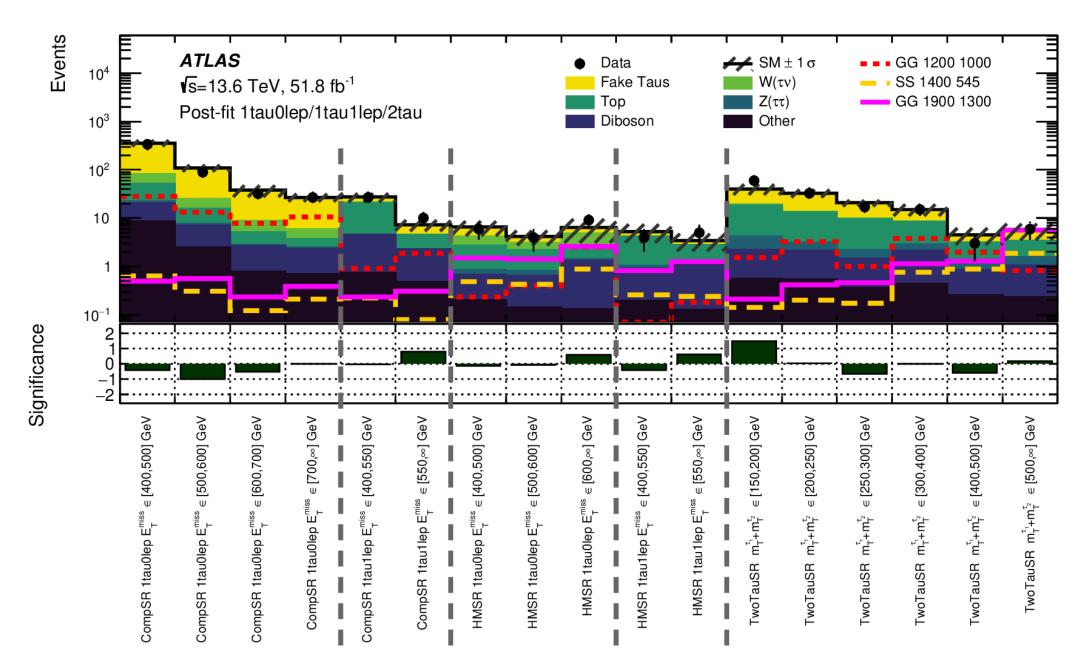
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CERN-EP-2025-132, submitted to EPJC





- Cut-and-count based:
 - 1τ compressed, 1τ high mass, 2τ high-mass
 - E_T^{miss} fitted in 1τ SRs and $m_T^{\tau 1} + m_T^{\tau 2}$ in 2τ SRs



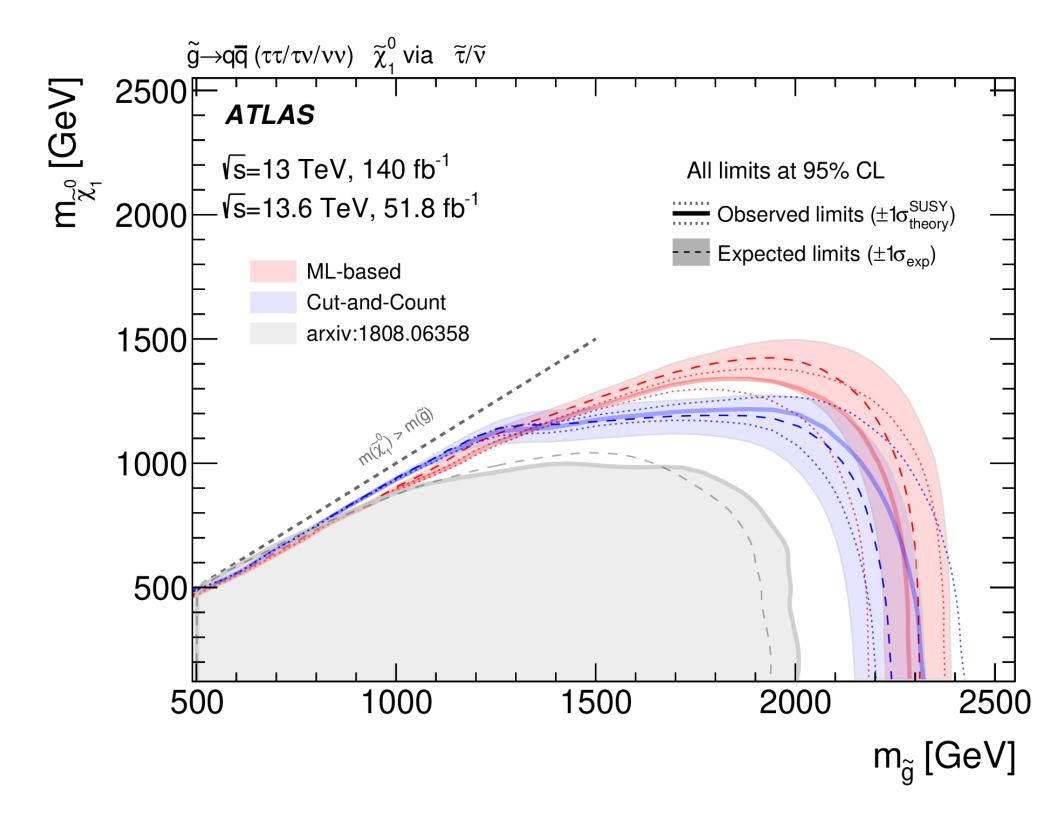


stable SUSY particle

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RPC squarks & gluinos: $\tau + E_T$ miss

- 1.35 TeV for gluino masses around 2 TeV



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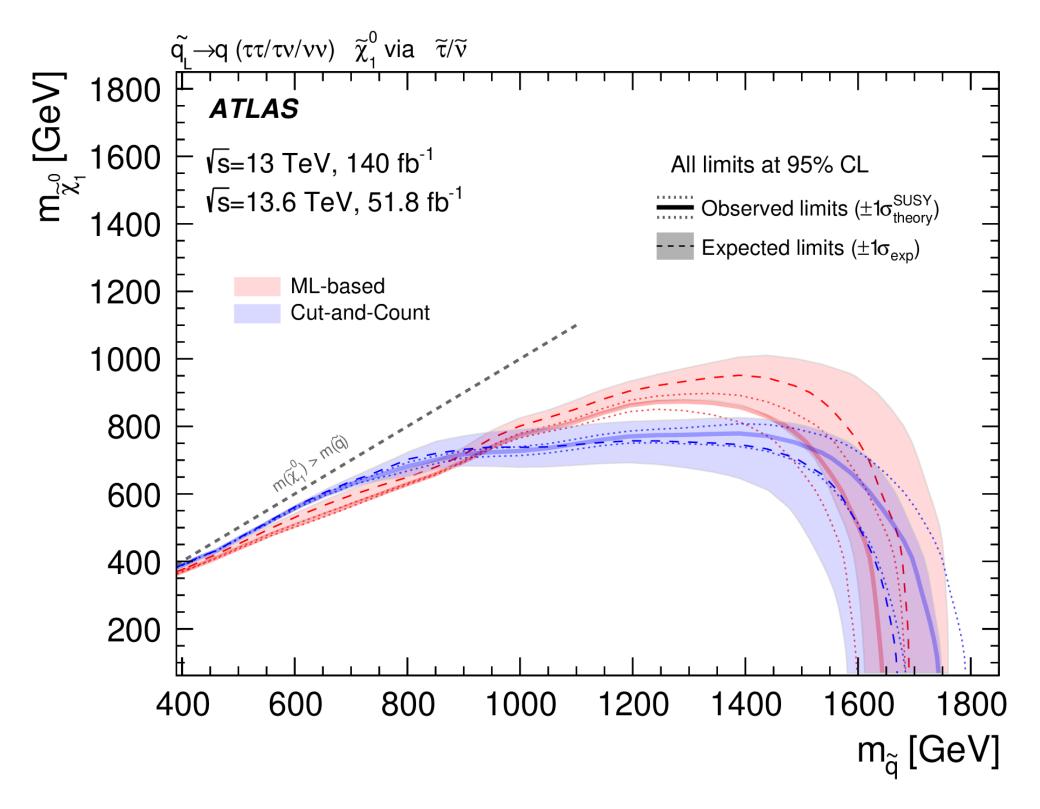




For **gluino** pair production models, gluino masses excluded below 2.25 GeV, and LSP masses excluded below

For squark pair production models, squark masses excluded up to 1.7 TeV, and LSP masses up to 0.85 TeV

The cut-and-count-based approach slightly better in **compressed** region thanks to dedicated optimised region



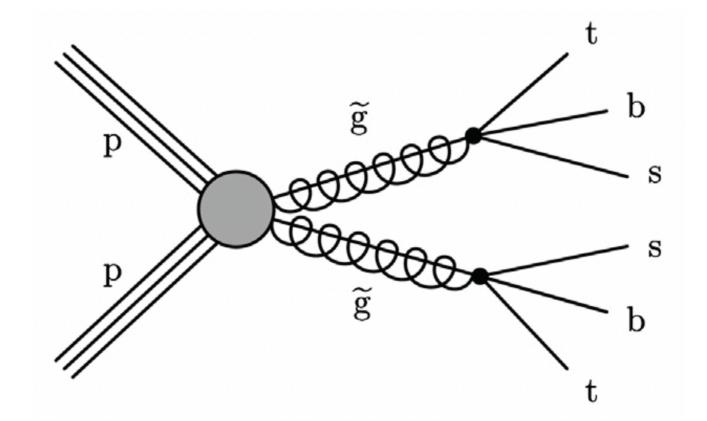


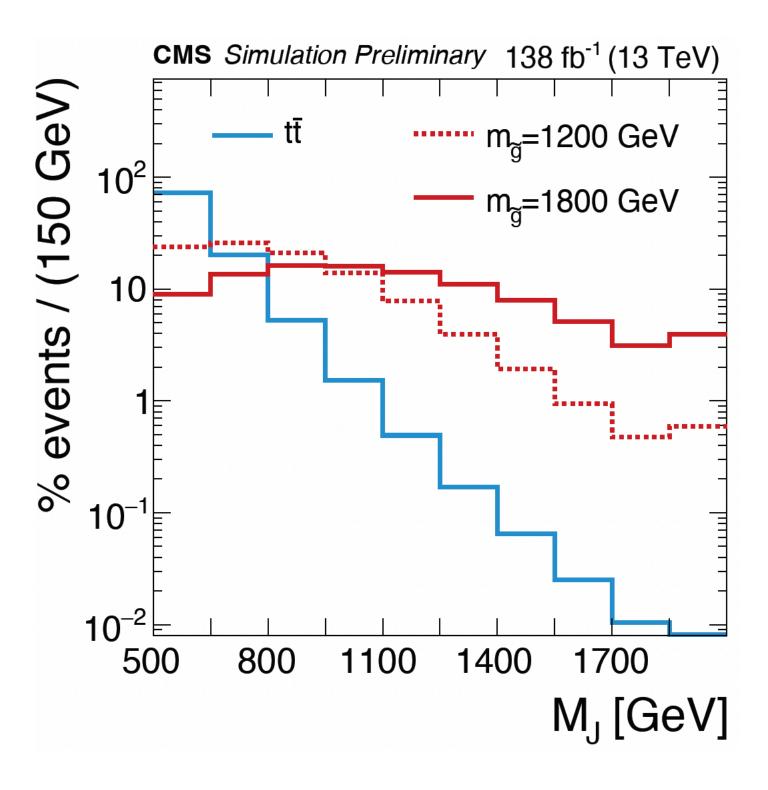




- Search for BSM with **high jet and b-jet multiplicities** in the single-lepton final state, without a requirement on E_T^{miss}
- Focus on **gluino pair production**, where each gluino decays to a top, a bottom, and a strange quark via the λ_{332}'' coupling (RPV)
- The scalar sum of the large-radius jet masses (M_J) templates are fitted to data in bins of N_{jet} and N_{bjet}
 - Determine the normalisation of the main backgrounds (QCD, W+jets, and tt̄) in each (N_{jet} and N_{bjet}) bin
- Data-driven correction factors are derived in $3 M_J$ regions (500-800, 800-1100, ≥ 1100) GeV

SUS-21-005



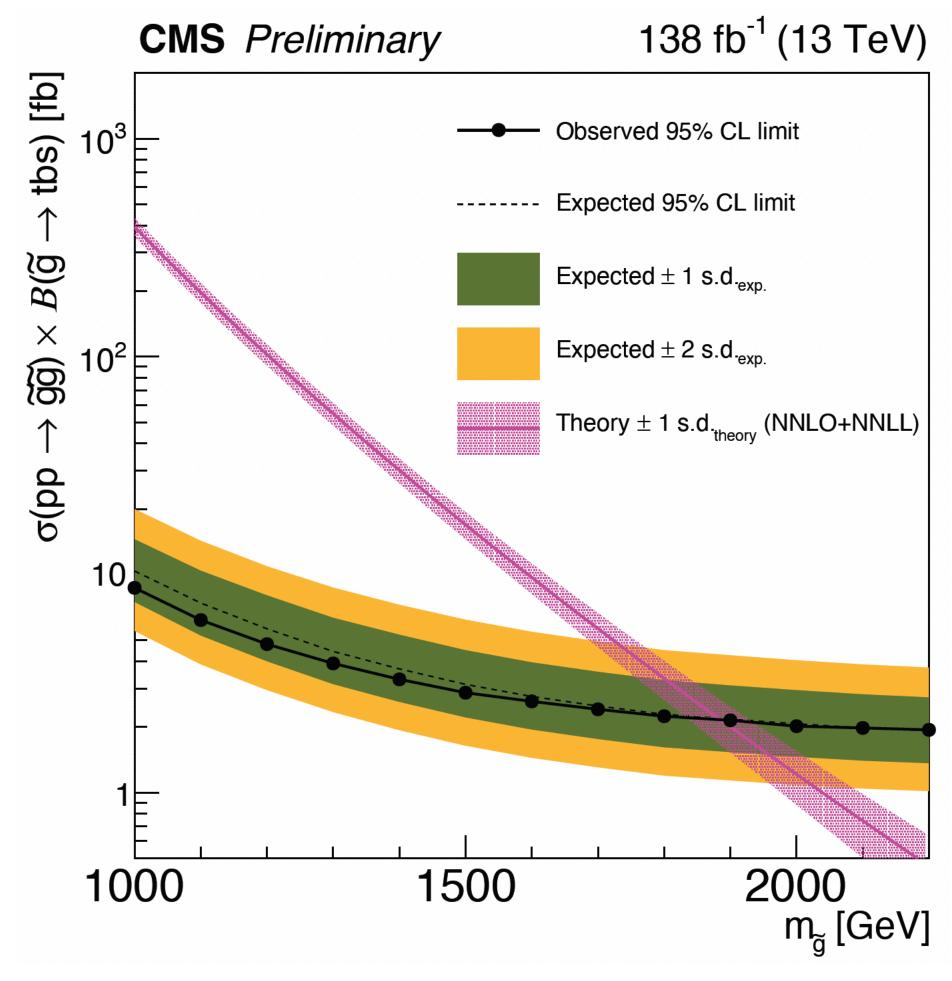






RPV SUSY 12 + multi-(b)jets

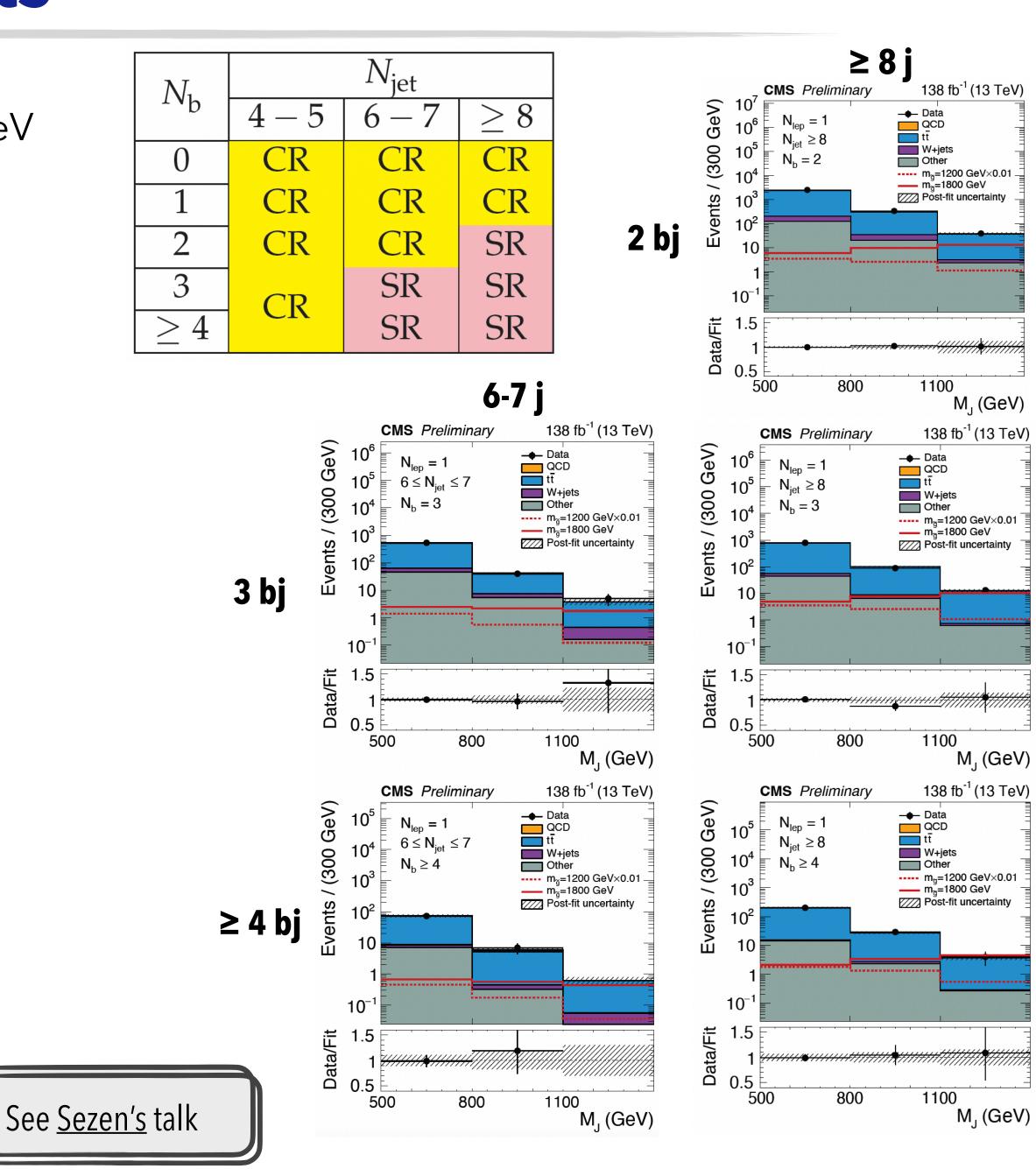
• Gluinos are excluded up to a mass of 1890 GeV at the 95% confidence level



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SUS-21-005





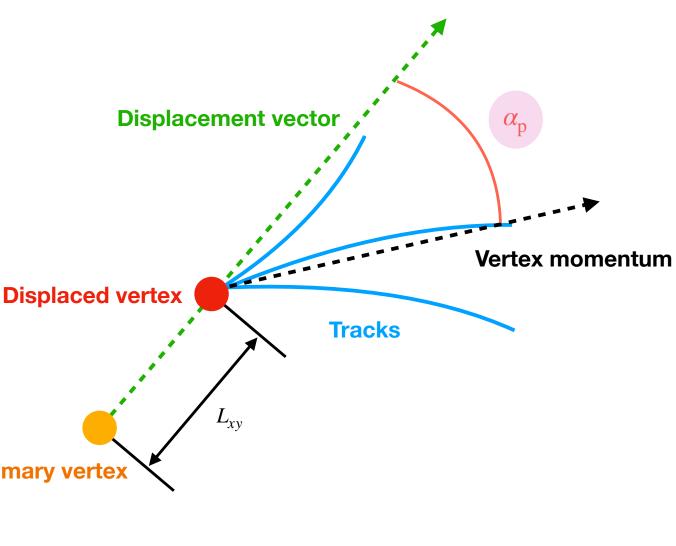


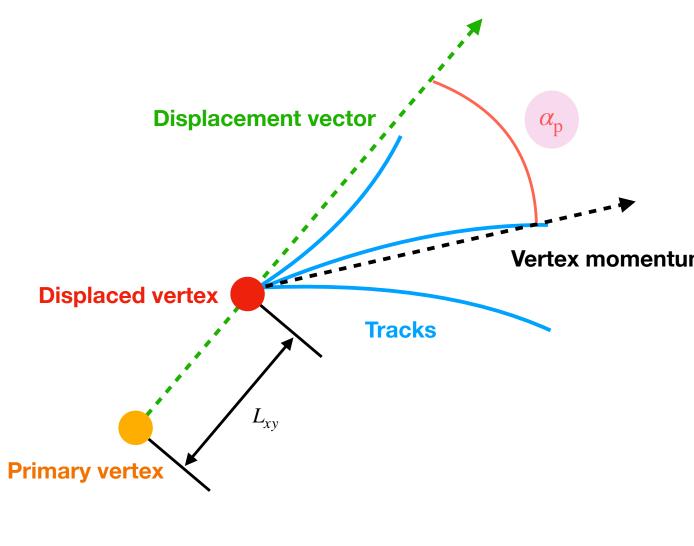


SUSY co-annihilation with LLP

- Search for LLPs in signatures of **low-p_T displaced vertices**, p_T^{miss}, and an ISR jet
- Co-annihilation scenarios characterised by a **long-lived** next-to-lightest SUSY particle (NLSP) with a mass difference of less than 25 GeV relative to the lightest SUSY particle (LSP)
 - Top squark scenario: the NLSP is a top squark, while the LSP is a bino-like neutralino
 - Bino-wino scenario: the NLSPs are long-lived wino like neutralino and prompt wino-like chargino, and the LSP remains a bino-like neutralino
 - First LHC search sensitive to this regime! _

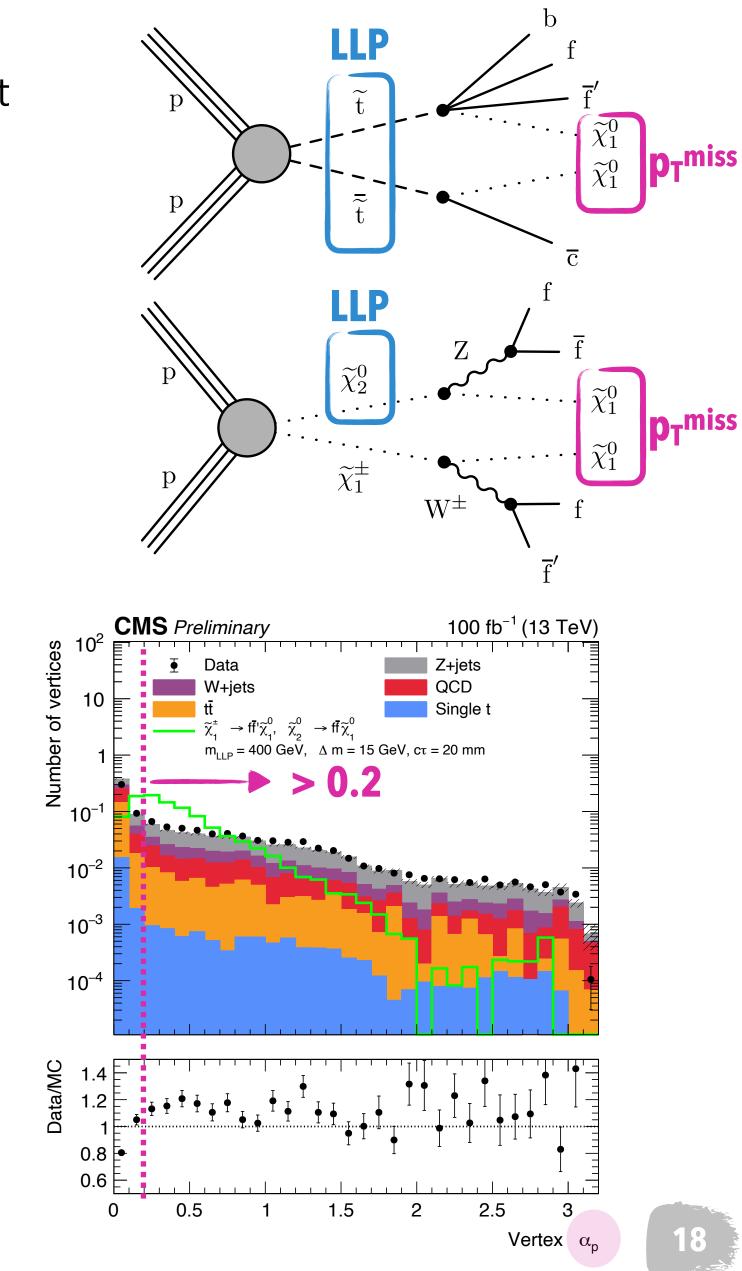
Reconstruct displaced vertices using a customised reconstruction algorithm





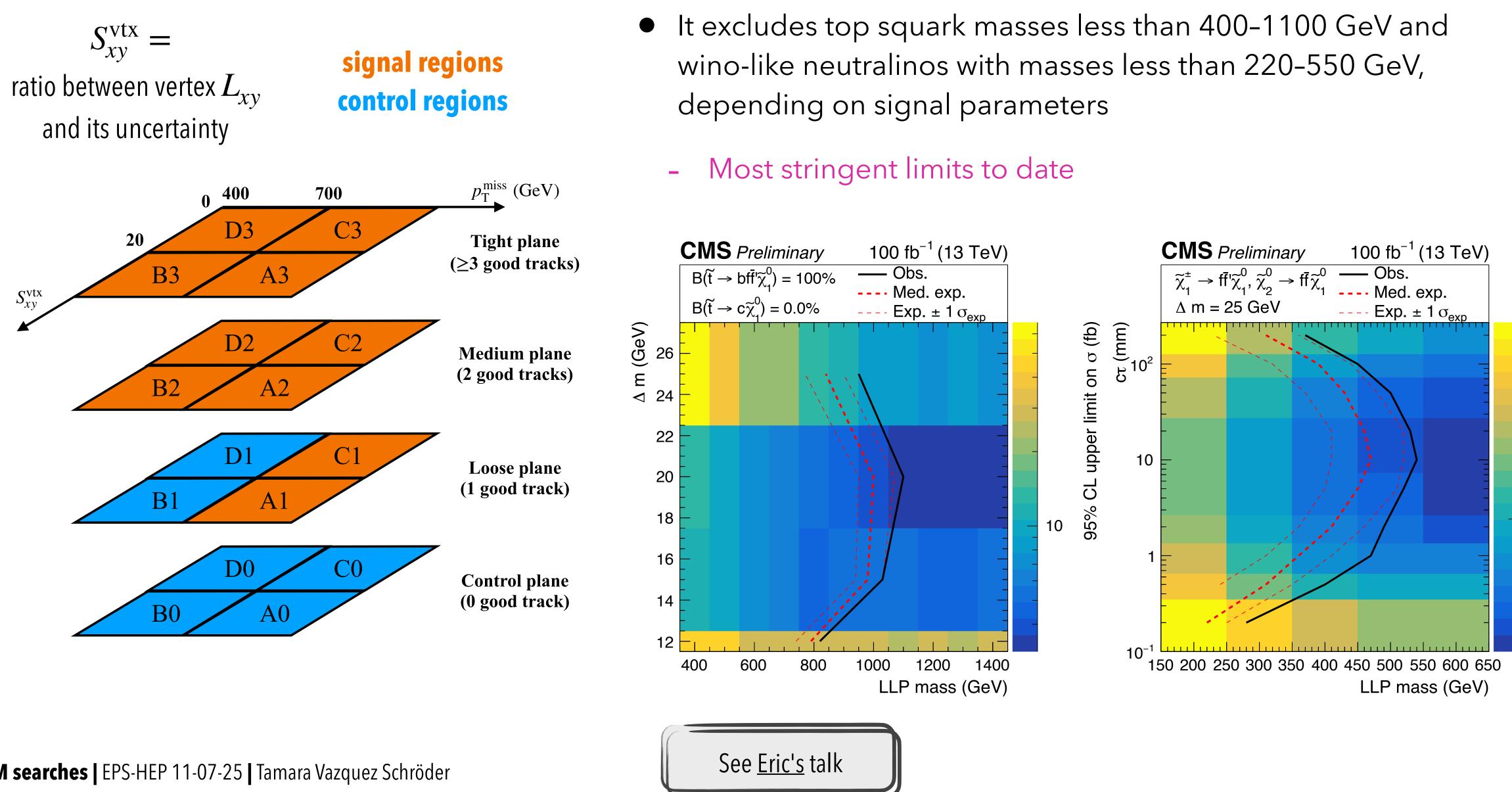
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CMS-PAS-EXO-24-033





SUSY co-annihilation with LLP

















Two-Higgs-doublet-model (2HDM)

- Extension of the electroweak Higgs sector by another scalar doublet
- Pheno contains a charged Higgs, a pseudoscalar and two neutral scalars, flavour-changing neutral currents, and more possibilities for CP violation and baryogenesis

BSM (in) Higgs

exotics H decays X→SH→bbyy $X \rightarrow YH \rightarrow VV(4q)bb$

Exotic Higgs decays

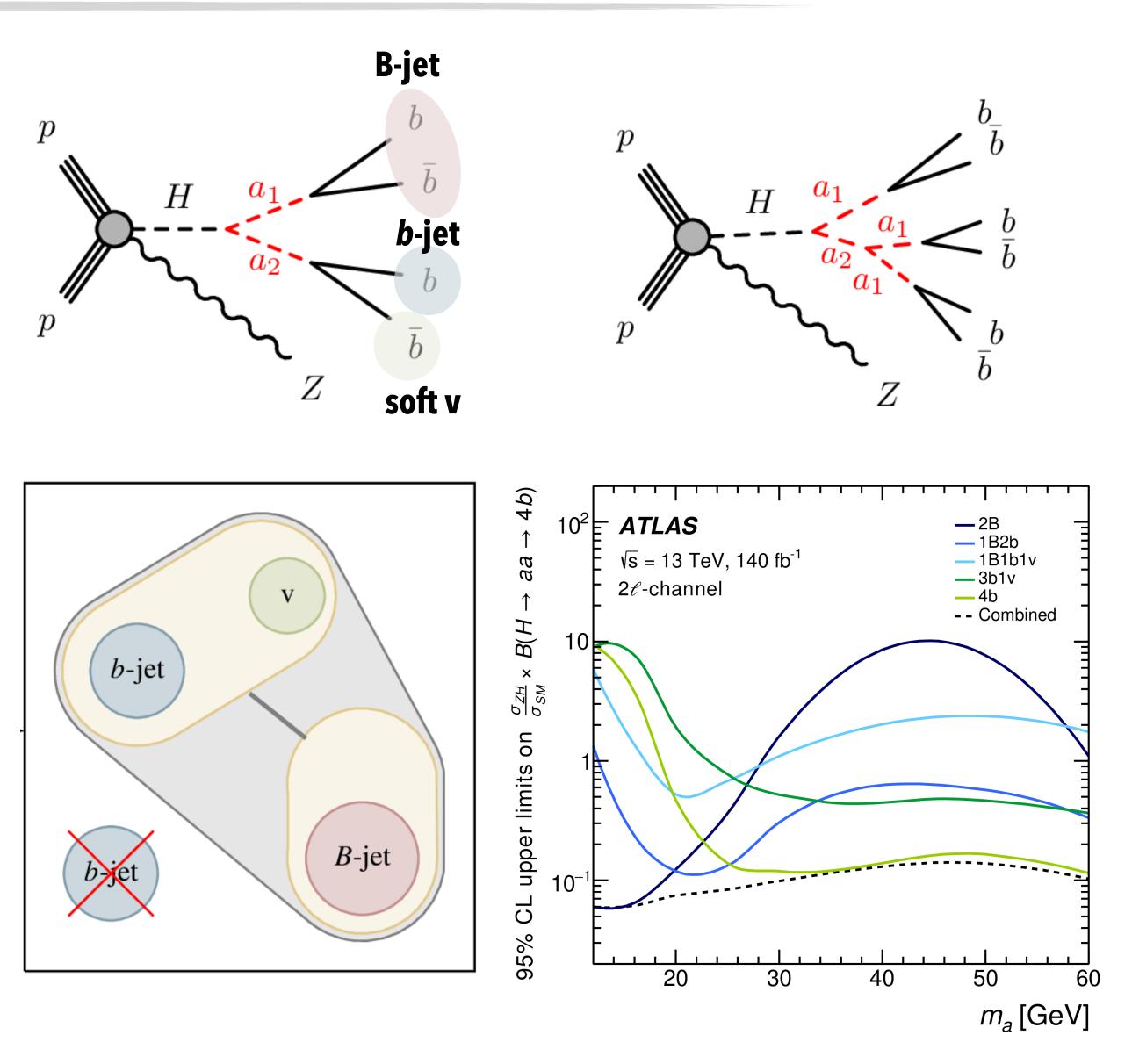
- Higgs boson decays are particularly sensitive to new physics due to the small total width
- Models predicting new light scalar(s) can lead to exotic Higgs decays, e.g.: $H \rightarrow a_1a_2 \rightarrow 4b$ or $H \rightarrow a_1a_2 \rightarrow a_1a_1a_1 \rightarrow 6b$



- Searches for exotic Higgs decays to new light pseudoscalar "a"
 - bb dominant decay mode
- Target ZH production, with:
 - **Z→ℓℓ** (2ℓ, leptonic triggered)
 - 224b and 226b: BDT for S-vs-B in each SR
 - $Z \rightarrow \nu \nu$ (0l, E_T^{miss} triggered)
- Using two ATLAS b-taggers: covers merged (B), intermediate, and resolved (b) regimes
- Additionally, use of soft secondary vertices reconstructed outside of jets (v)

CERN-EP-2025-121, submitted to PRD



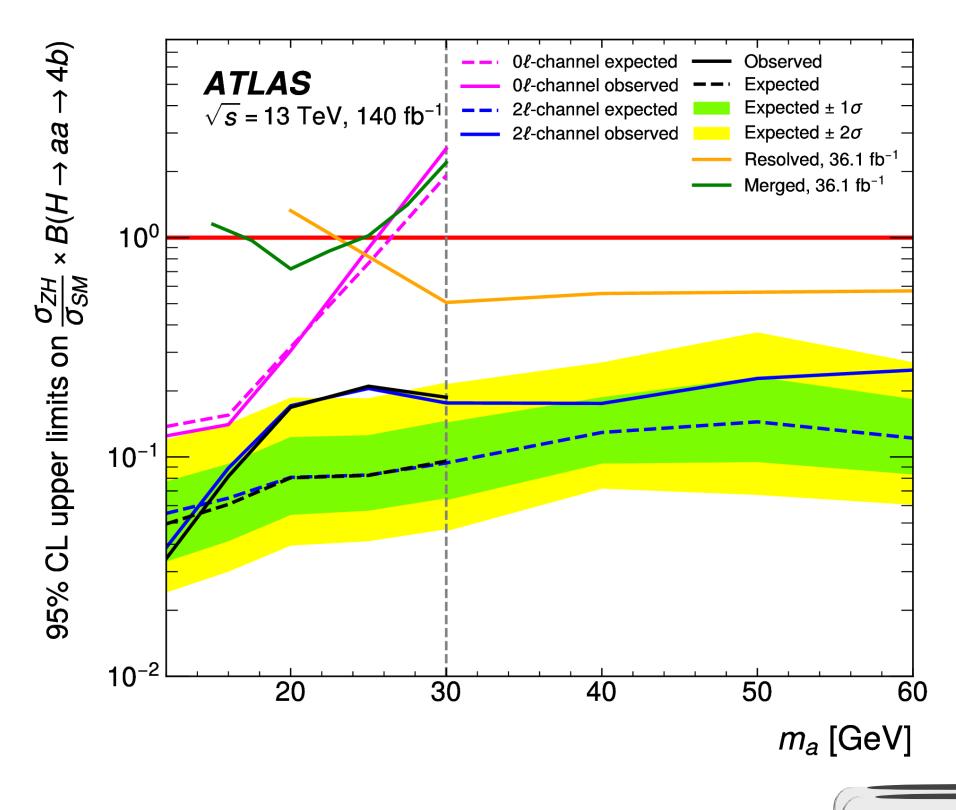






$ZH (H \rightarrow aa \rightarrow 4b/6b)$

- Most stringent limits of this model to date
- and to consider the $Z \rightarrow \nu \nu$ channel
- $m_a = 25 \text{ GeV}$ and **3.28 (2.57)** σ for $(m_{a1}, m_{a2}) = (50, 70) \text{ GeV}$

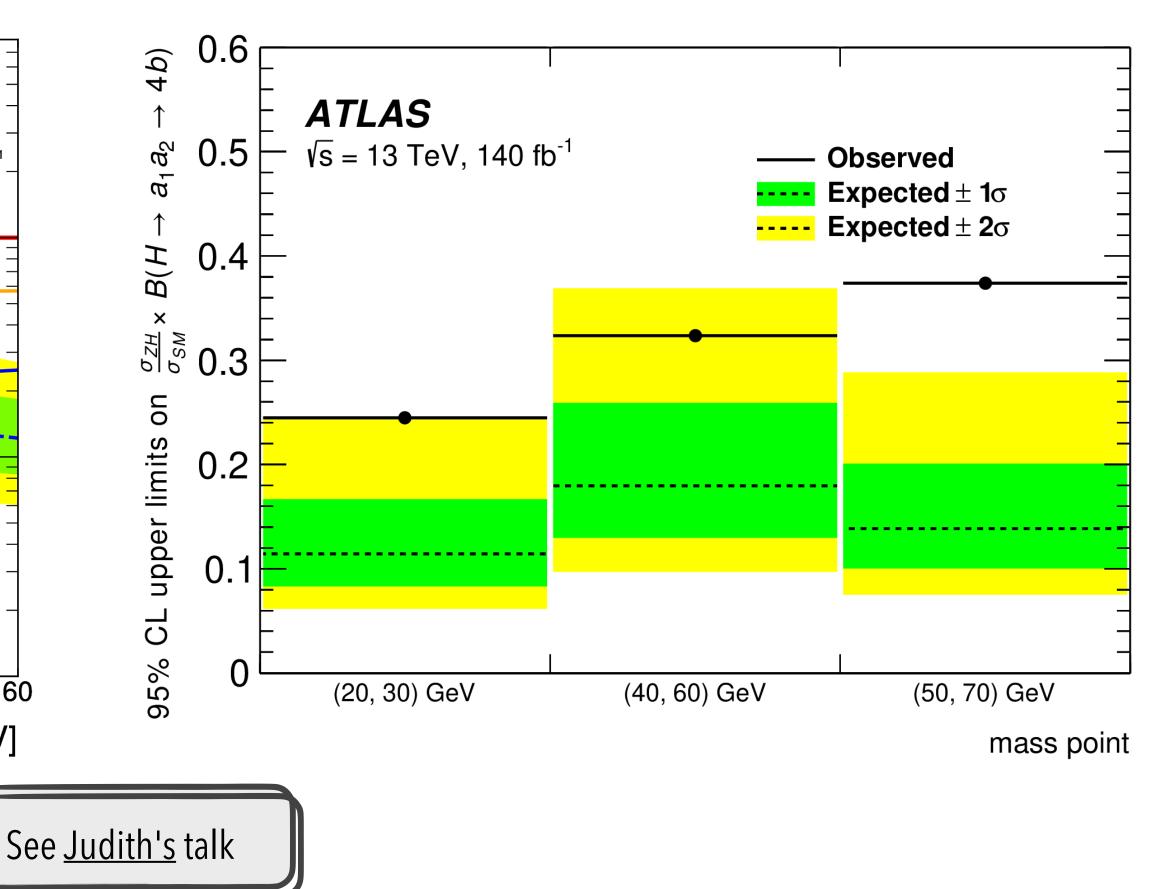


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First search to consider two additional scalars with different masses, including a cascade decay to 6b,

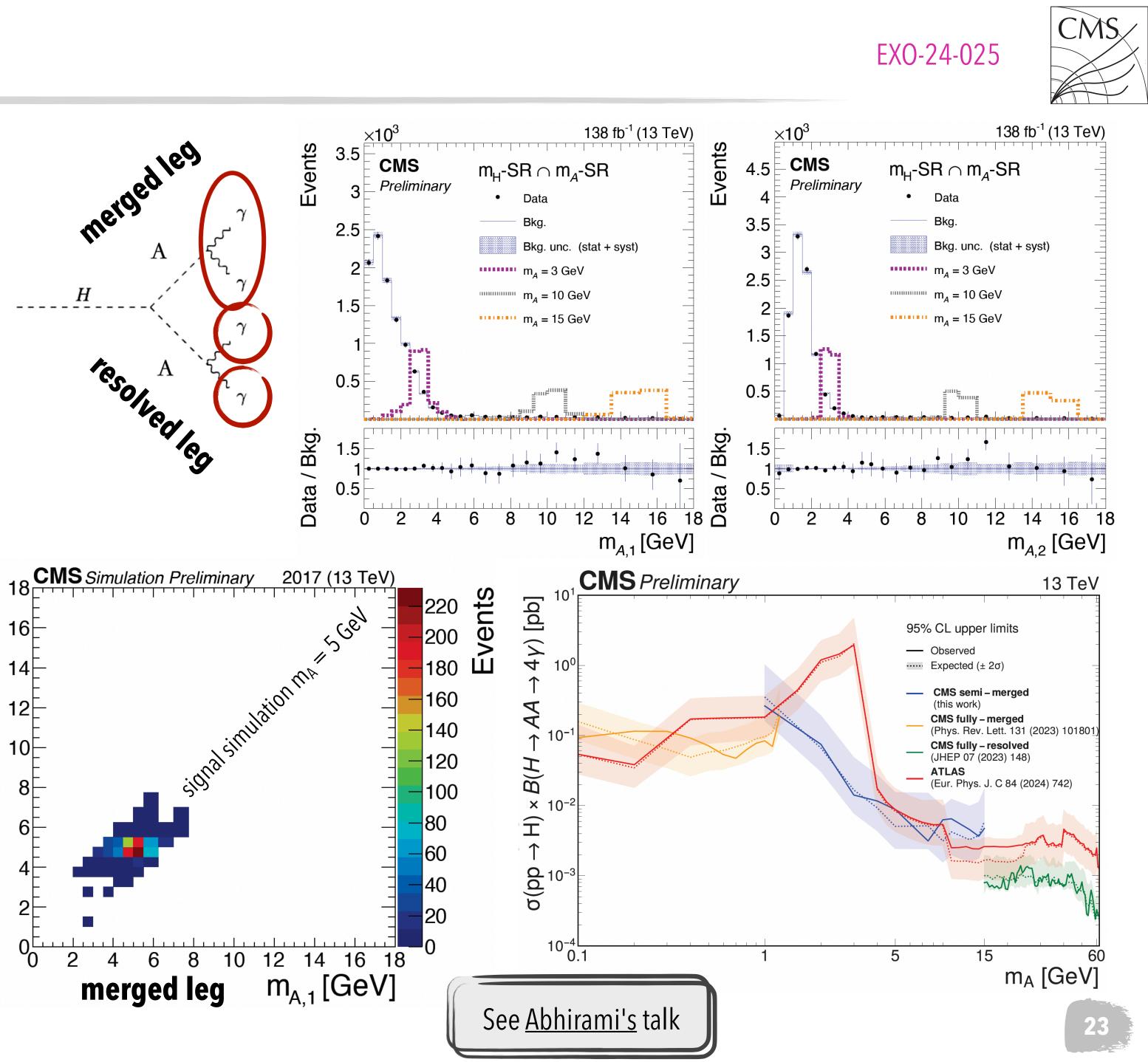
• Largest deviations in 4b regions in the 2 ℓ channel, with local (global) significance of **2.83 (2.04)** σ for

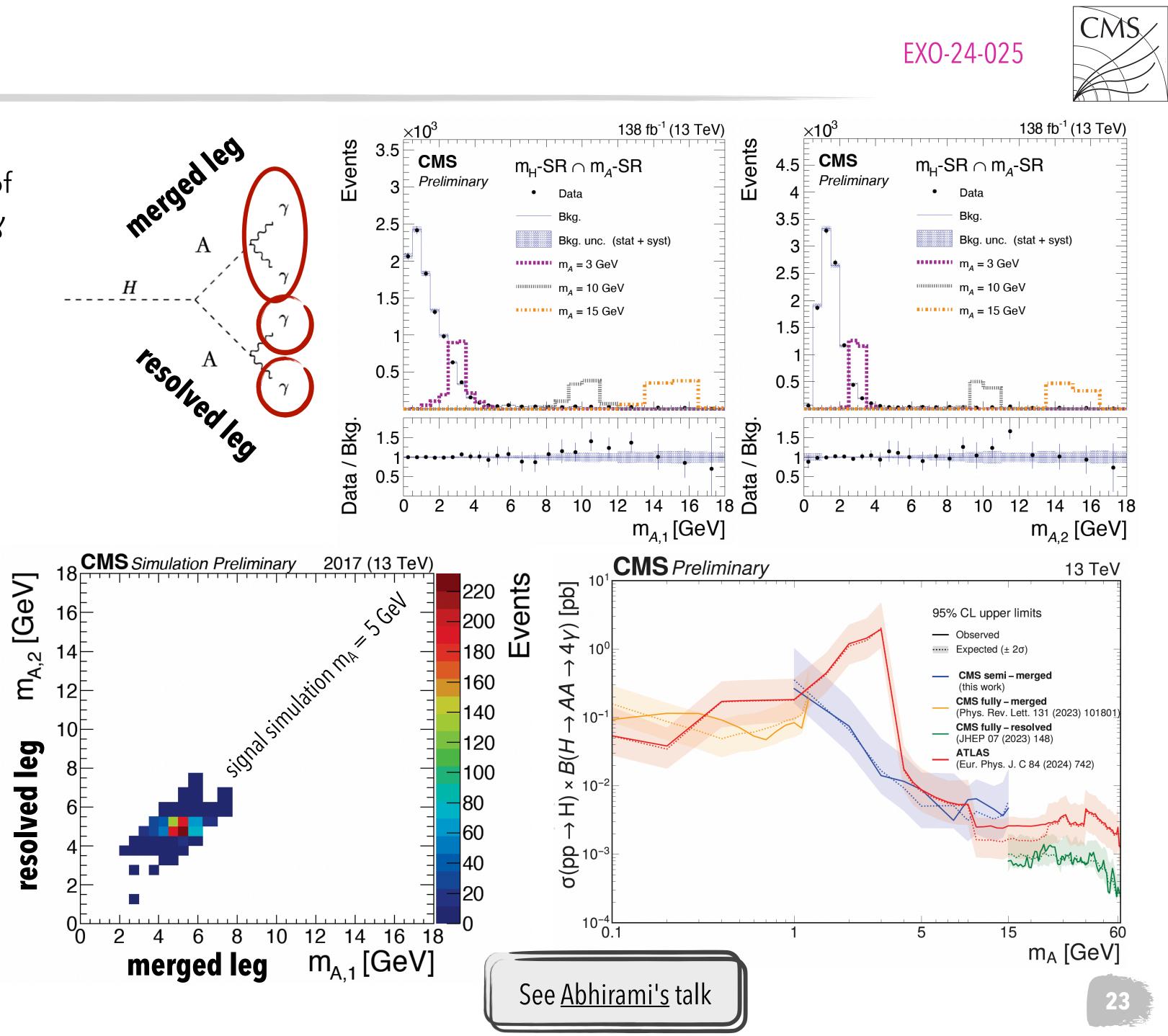






- Search for exotic Higgs decay to a pair of light pseudo-scalars $H \rightarrow AA$ with $A \rightarrow \gamma\gamma$
- Focus on three photon-like objects in the final state, to bridge the gap in the **1 < m_A < 15 GeV** mass range
- Novel deep-learning-based **mass** reconstruction technique developed: reconstructs m_A from pattern of energy deposits in ECAL crystals
- Signal and sideband regions defined along two axes:
 - Tri-photon mass m_{XXX} axis
 - 2D-m_A template axis
- Most stringent limits to date in the majority of the mass range explored



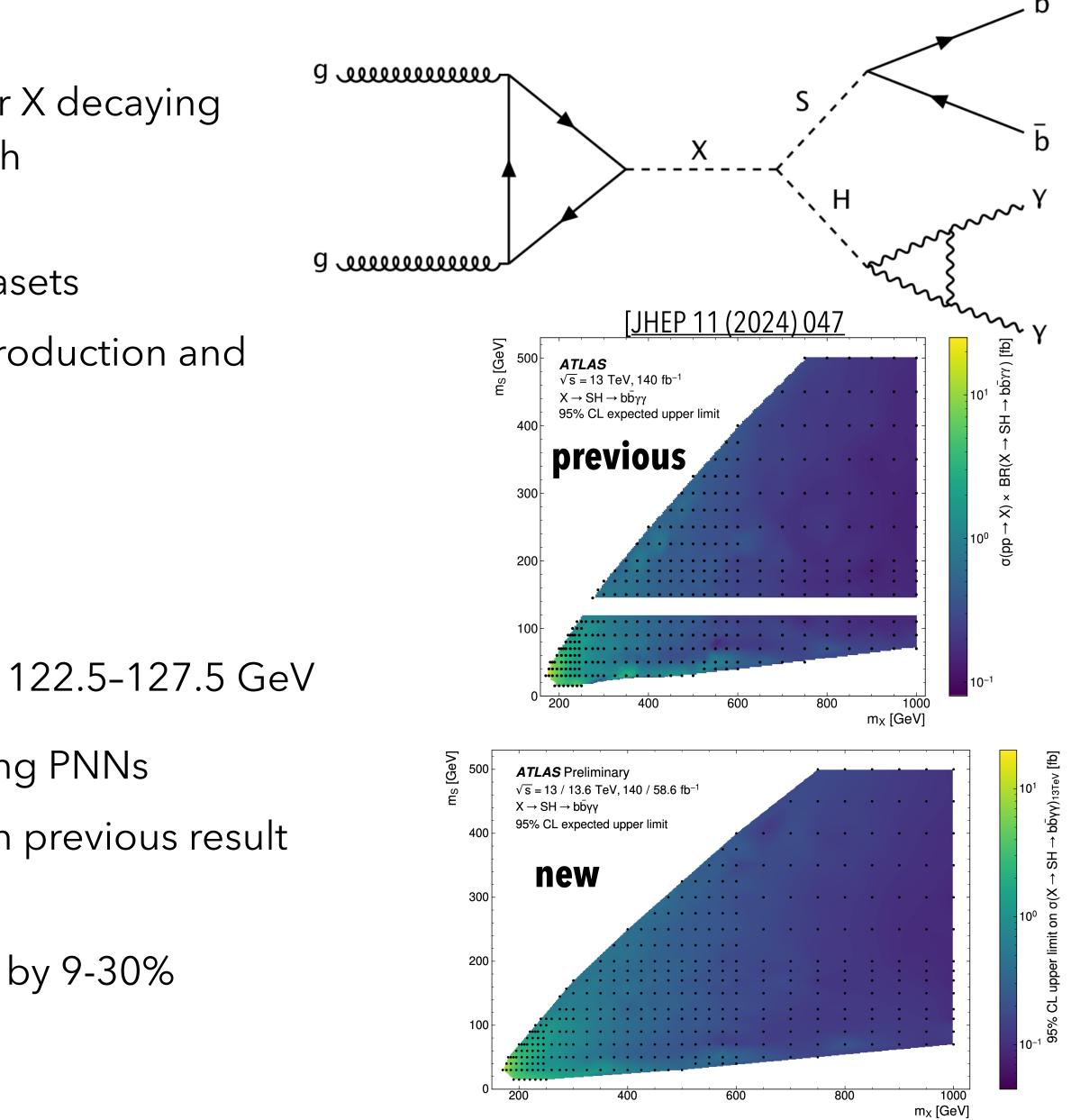




- Search for the resonant production of a heavy scalar X decaying into a SM Higgs boson and a lighter scalar S through X→SH→bbyy
- Using Run 2 (140 fb⁻¹) + partial Run 3 (58.6 fb⁻¹) datasets
- Main backgrounds: continuum di- γ non-resonant production and Higgs processes with H $\rightarrow \gamma \gamma$
- Main updates wrt. previous results:
 - Changing from DL1r to **GN2 b-tagger**
 - m_{yy} requirement changed from 120–130 GeV to 122.5–127.5 GeV
- Two SRs based on the number of b-tagged jets, using PNNs
- Expected limits on $\sigma_{13 \text{ TeV}}$ are 15% to 73% lower than previous result (largest improvements on low-mass region)
- Inclusion of early Run 3 dataset improves sensitivity by 9-30%





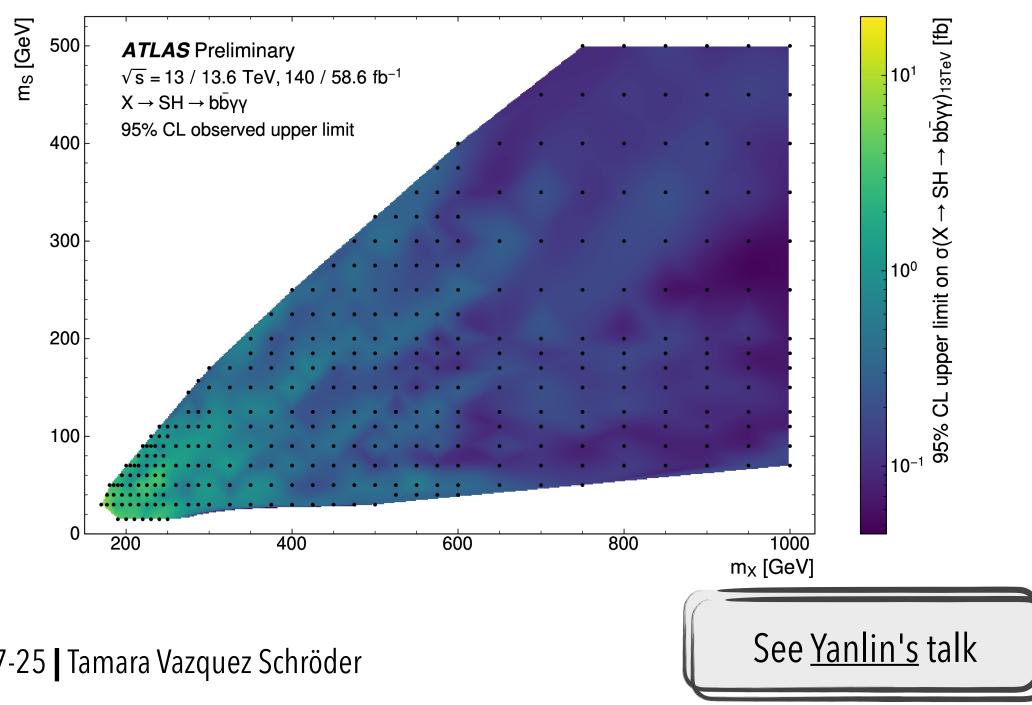






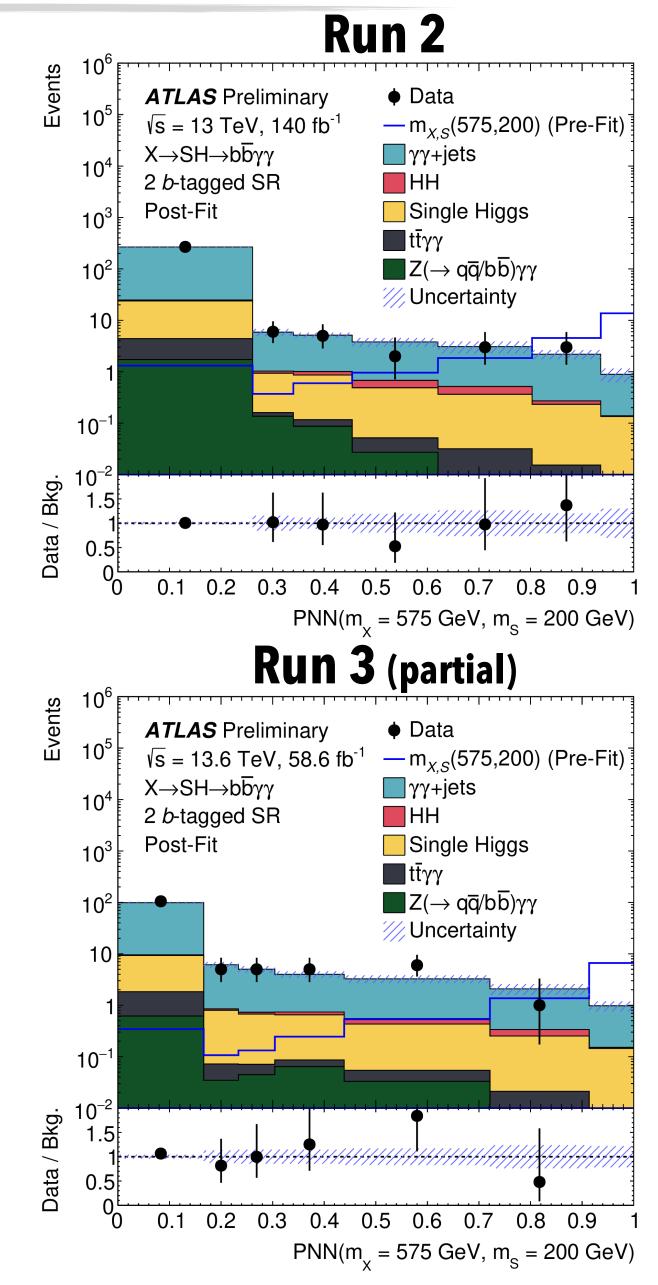


- Largest deviation from the B-only hypothesis from previous results:
 - ATLAS [JHEP 11 (2024) 047]: $(m_X, m_S) = (575, 200)$ GeV with a local (global) significance of 3.5 (2.0) σ
 - CMS [JHEP 05 (2024) 316]: $(m_X, m_S) = (650, 90)$ GeV with a local (global) significance of 3.8 (2.8) σ
- No similar deviation as previous ATLAS result, neither in Run 2 nor Run 2 + Run 3









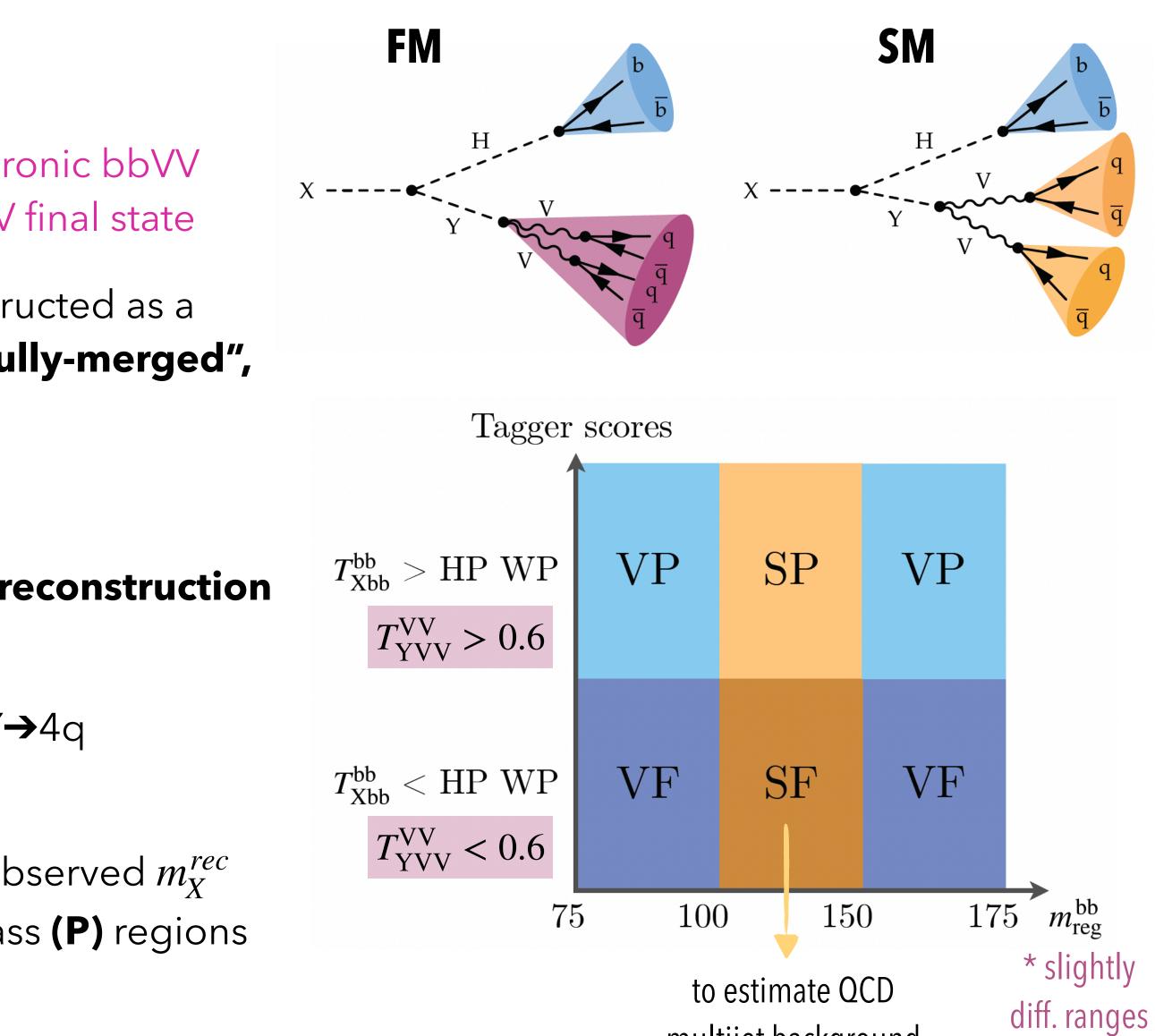


25



- First search at the LHC for scalar resonances in all-hadronic bbVV final state and asymmetric cascade decays in the bbVV final state
- Lorentz-boosted regime: H→bb decay can be reconstructed as a single large-area jet, and Y→VV→4q as one Y→4q ("fully-merged", or FM) or two V→qq jets ("semi-merged", or SM)
- Events selected with H_T and large-area jet triggers
- Machine-learning-based jet identification and mass reconstruction algorithms:
 - Novel attention-based "particle transformer" for Y→4q discrimination
- 2D binned maximum likelihood fit performed to the observed m_X^{rec} and m_Y^{rec} distributions, simultaneously in fail (**F**) and pass (**P**) regions

B2G-23-007



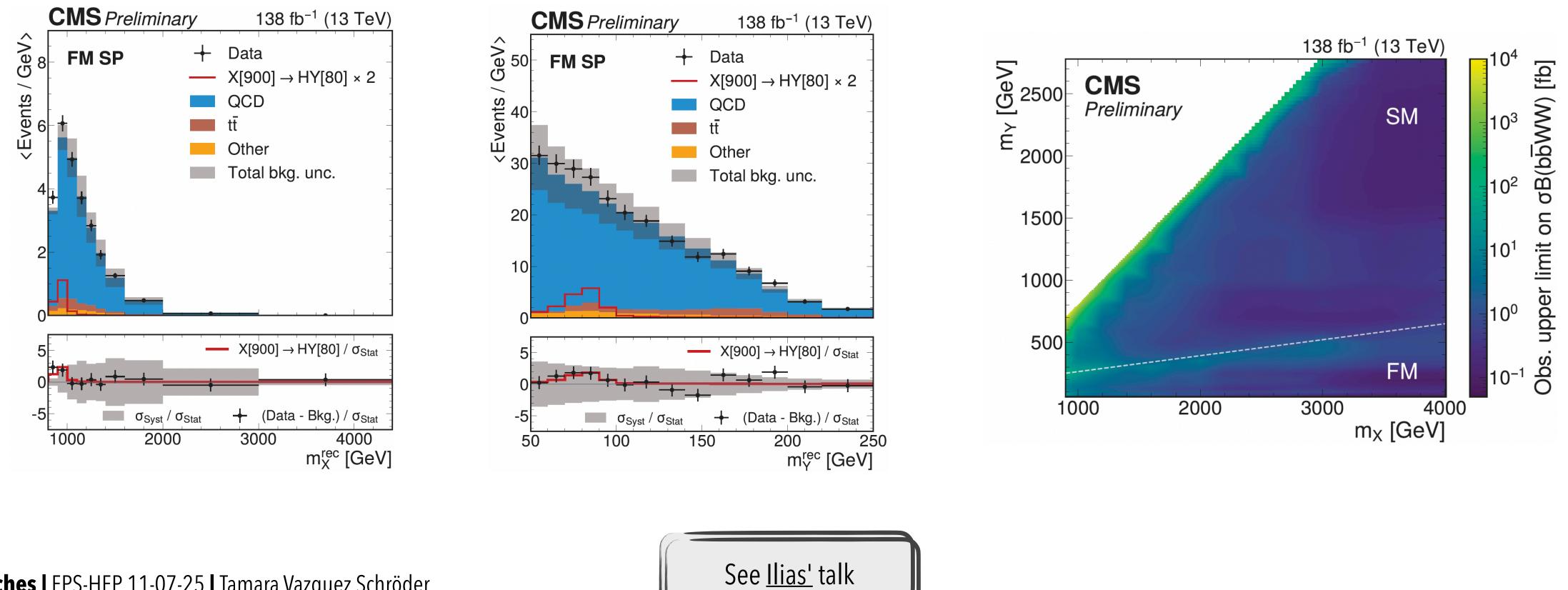
multijet background







- Largest deviation from the background-only hypothesis is observed for $m_X = 900$ GeV and $m_Y = 80$ GeV with a local (global) significance of **3.3** (< 1.0) σ
- Upper limits as low as 0.1 fb are derived at the 95% confidence level for various mass points









Dark Sector

dark H multi-b dark γ and H (LLP to μ)

Dark Higgs model

- Naturally satisfies observed relic density
- Massive DM and Z' from dark sector Higgs mechanism

Dark Photon

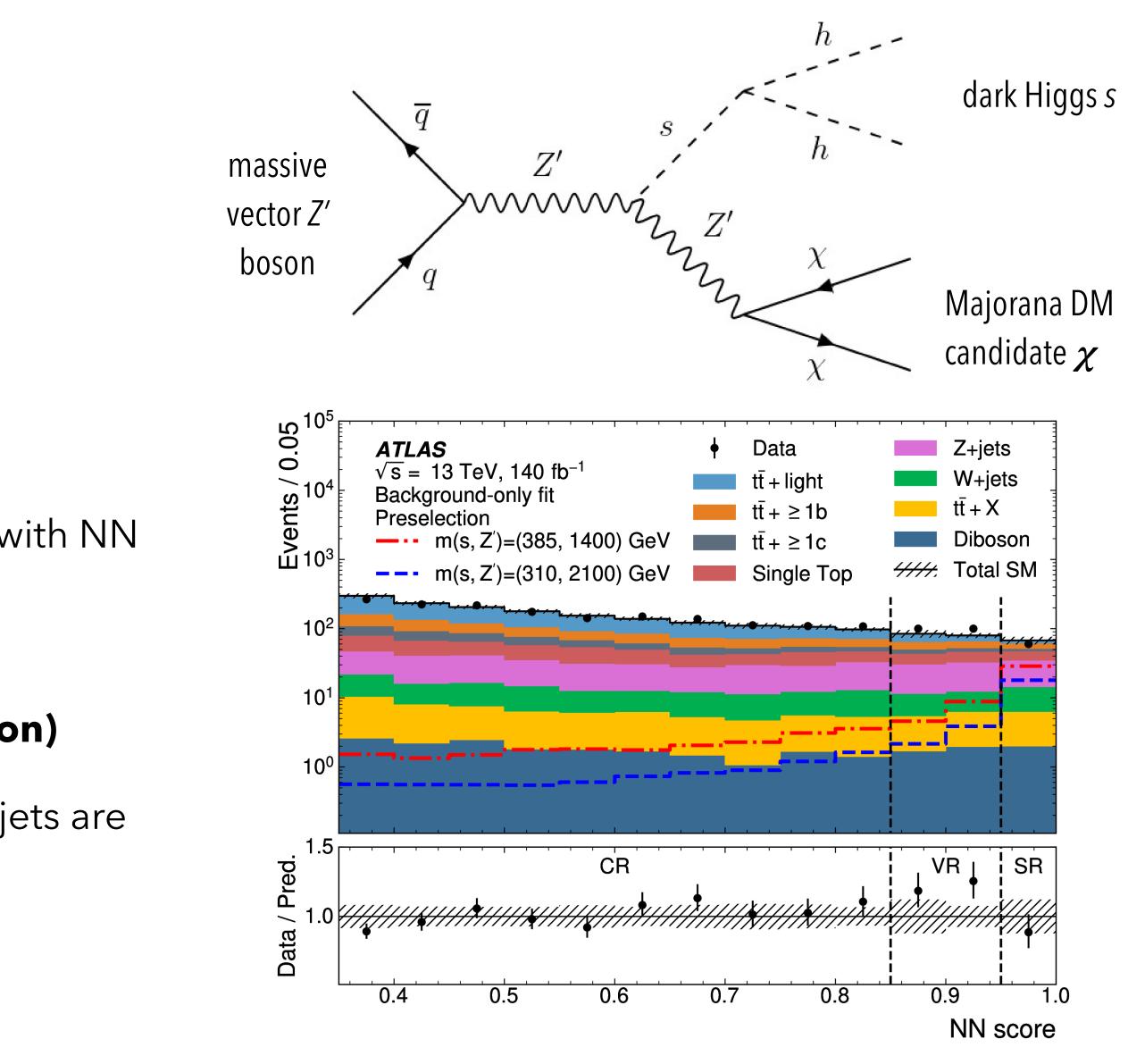
• Z_D, mediator of a broken dark U(1) gauge theory that kinetically mixes with SM hypercharge • If the dark U(1) is broken by hidden-sector Higgs mechanism, then mixing between dark and SM Higgs bosons also allows exotic decay $h \rightarrow Z_D Z_D$



Dark Higgs, multi-b + p_Tmiss

- First search for resonant hh + E_Tmiss at the LHC
- Resonant topology, 4b back-to-back with p_T^{miss}
 - Selections made on p_T^{miss}-based variables
 - Pair b-jets to form Higgs candidates
 - Define control, validation and signal regions with NN score
- Perform fit and statistical interpretation on fully reconstructable dark Higgs mass (m_{hh} distribution)
- Normalisation factors for $t\bar{t}+\geq 1b$, $t\bar{t}+light$ and Z+jets are free-floating



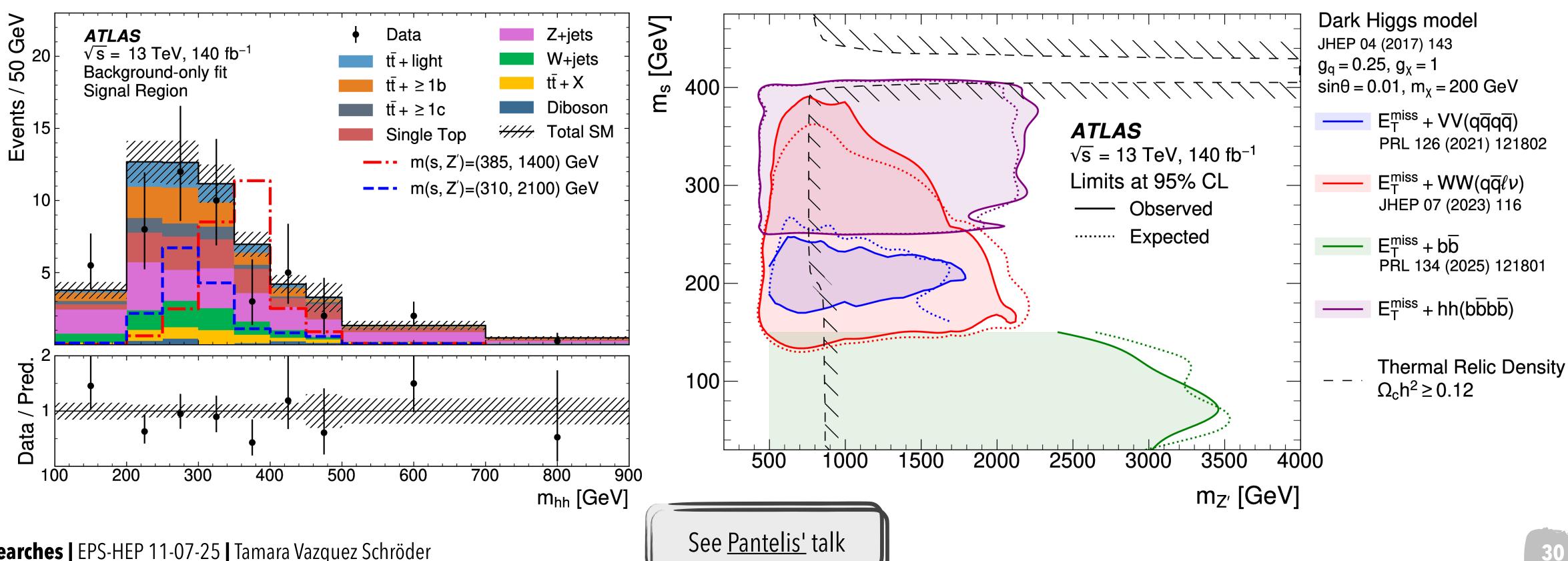






Dark Higgs, multi-b + p_Tmiss

- Upper limits are derived on BSM particle masses for $250 < m_s < 400$ GeV, excluding Z' masses up to 2.3 TeV
- Significantly extends existing constraints in this mass region from previous analyses
- Complement other lower-mass dark Higgs boson searches, searches for extended Higgs sectors and other collider DM searches

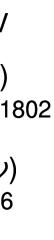


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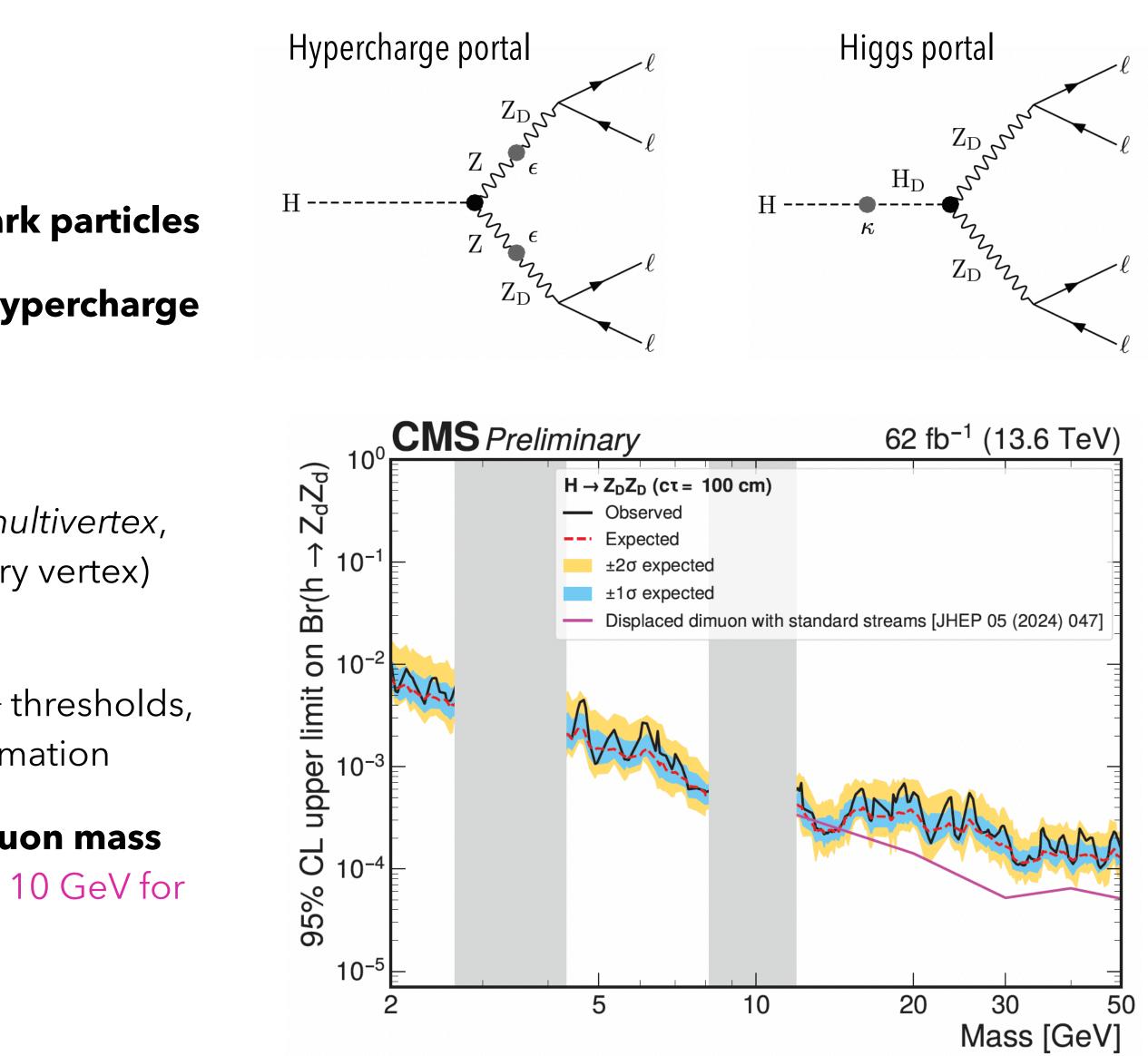






- Search for displaced multi-muon resonances
- BSM models where a Higgs boson decays to **long-lived dark particles**
 - The hidden sector may interact with SM either through **hypercharge portal**, or **Higgs portal** via a dark Higgs boson H_D
- Analysed 2022+2023 Run 3 dataset (62.6 fb⁻¹)
- Events classified in **four-muon** with overlapping vertex or multivertex, and **di-muon** with pointing or not pointing (to the secondary vertex) topologies
- Dedicated di-muon trigger stream (scouting) with low p_T thresholds, recorded at high rate by retaining reduced amount of information
 - Explore otherwise inaccessible phase space at low di-muon mass and non-zero displacement from the PV (masses below 10 GeV for the first time in a displaced muon analysis!)

EXO-24-016









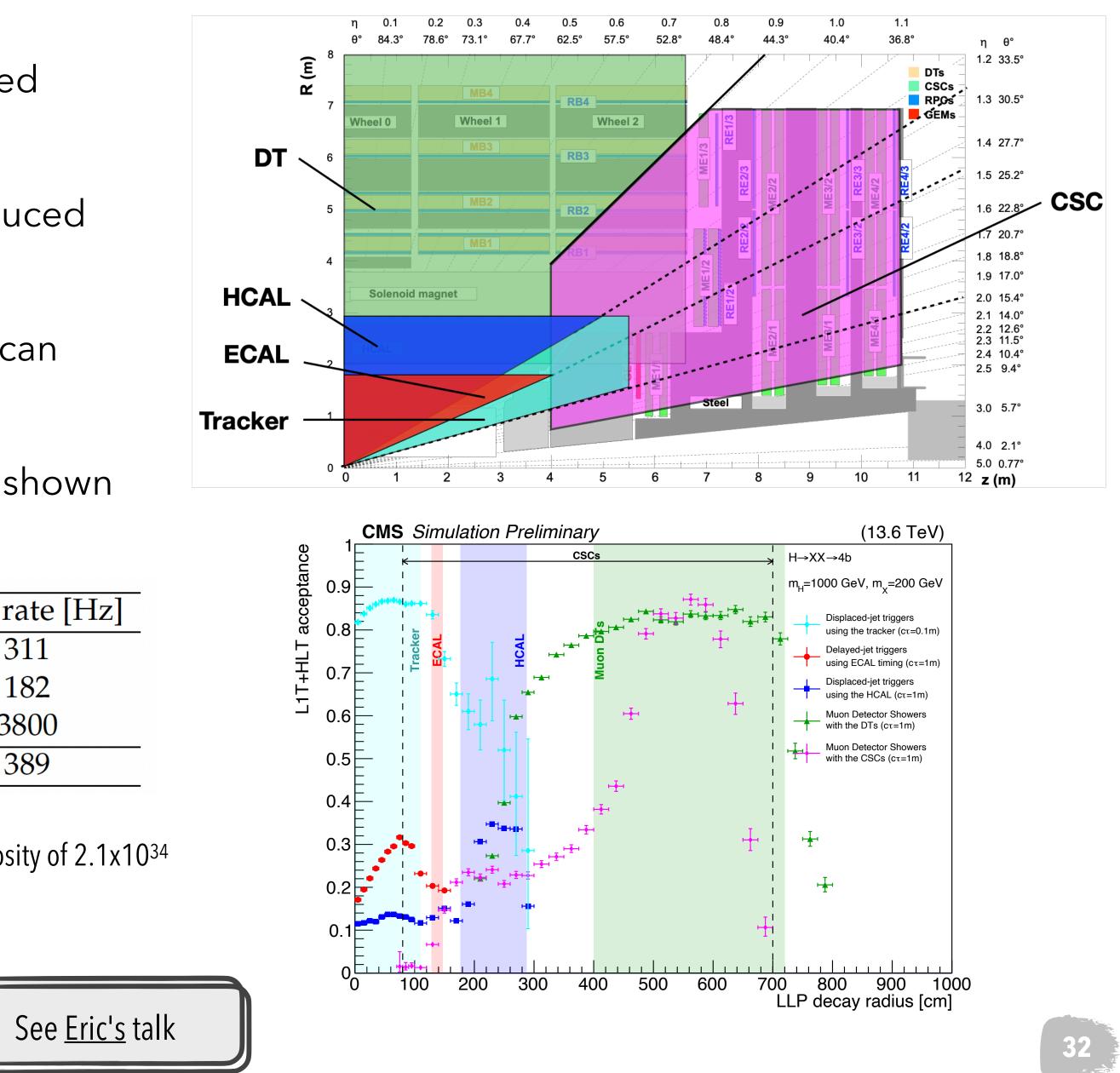


- Dedicated triggers targeting LLPs enable increased sensitivity to wide variety of signal models
- During Run 3, variety of such triggers were introduced and/or improved compared to Run 2
- Capitalise on different CMS subdetectors, hence can target different phase space in LLP searches
- The powerful complementarity of the program is shown using Twin Higgs model as a benchmark

Data	Total rate [Hz]	Pure r
Standard	393	3
Parking	234	1
Scouting	4200	3
Full reconstruction: standard or parking	586	3

- Calculated from one run in 2024 data for pile-up 63.6 and instantaneous luminosity of 2.1x10³⁴
- Total rate: **OR of LLP HLT trigger paths**, accounting for overlaps
- Pure rate: total rate not saved by any other HLT path

EXO-23-016

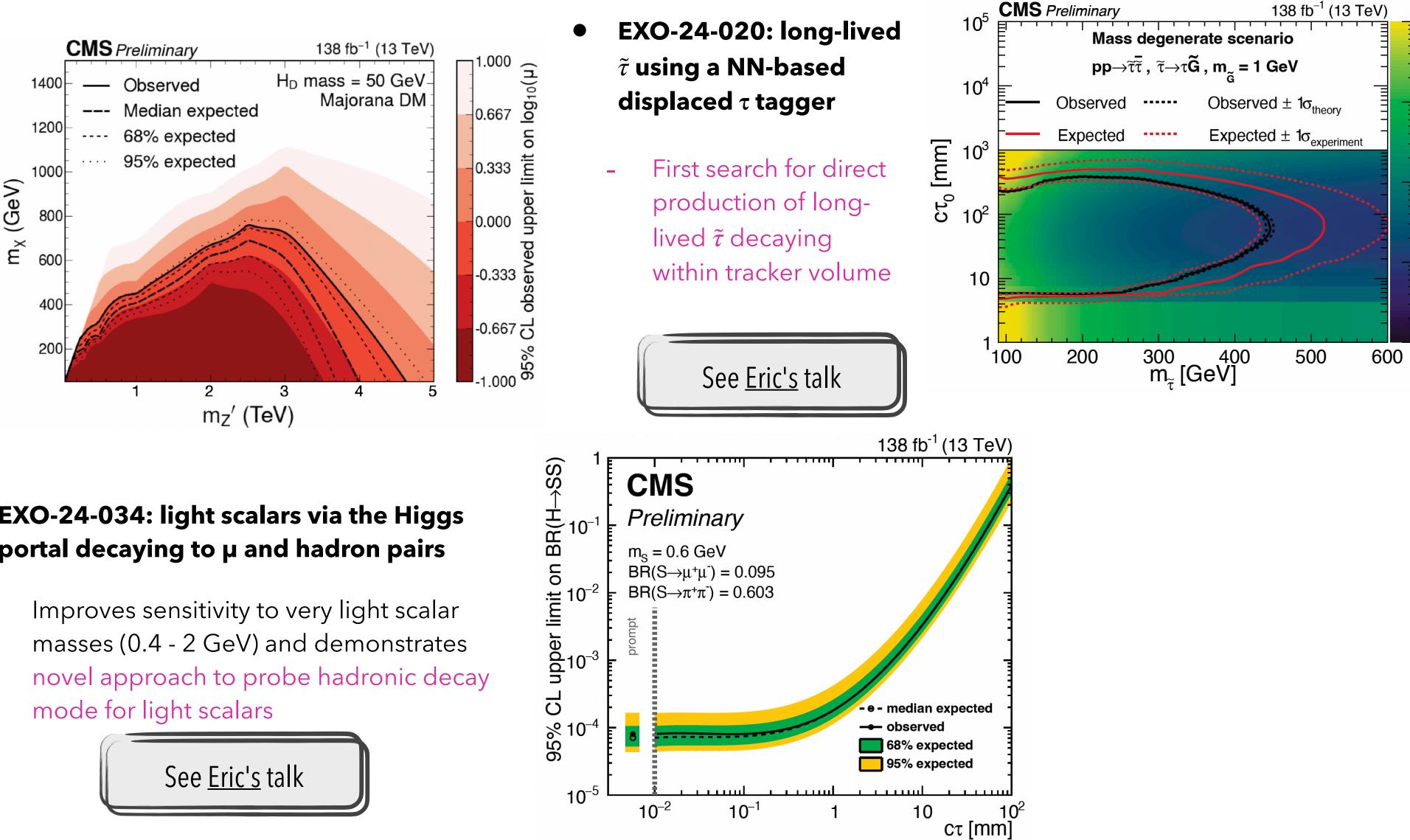




Even more new results (but not enough time to cover them)

- SUS-23-013: dark Higgs to bb
 - 95% CL limits on signal strength for dark Higgs boson masses below 160 GeV set for the first time with CMS data

See <u>Sushil's</u> talk



- **EXO-24-034: light scalars via the Higgs** portal decaying to **µ** and hadron pairs
 - -



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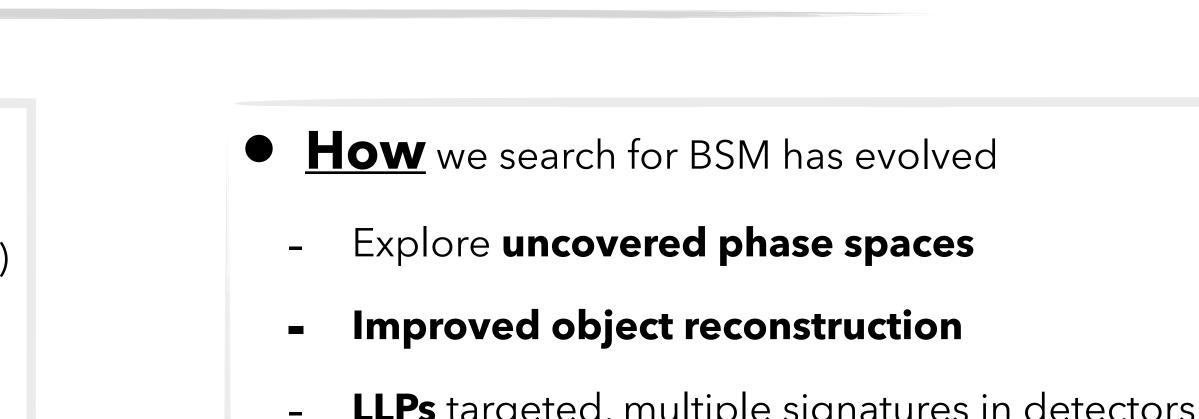


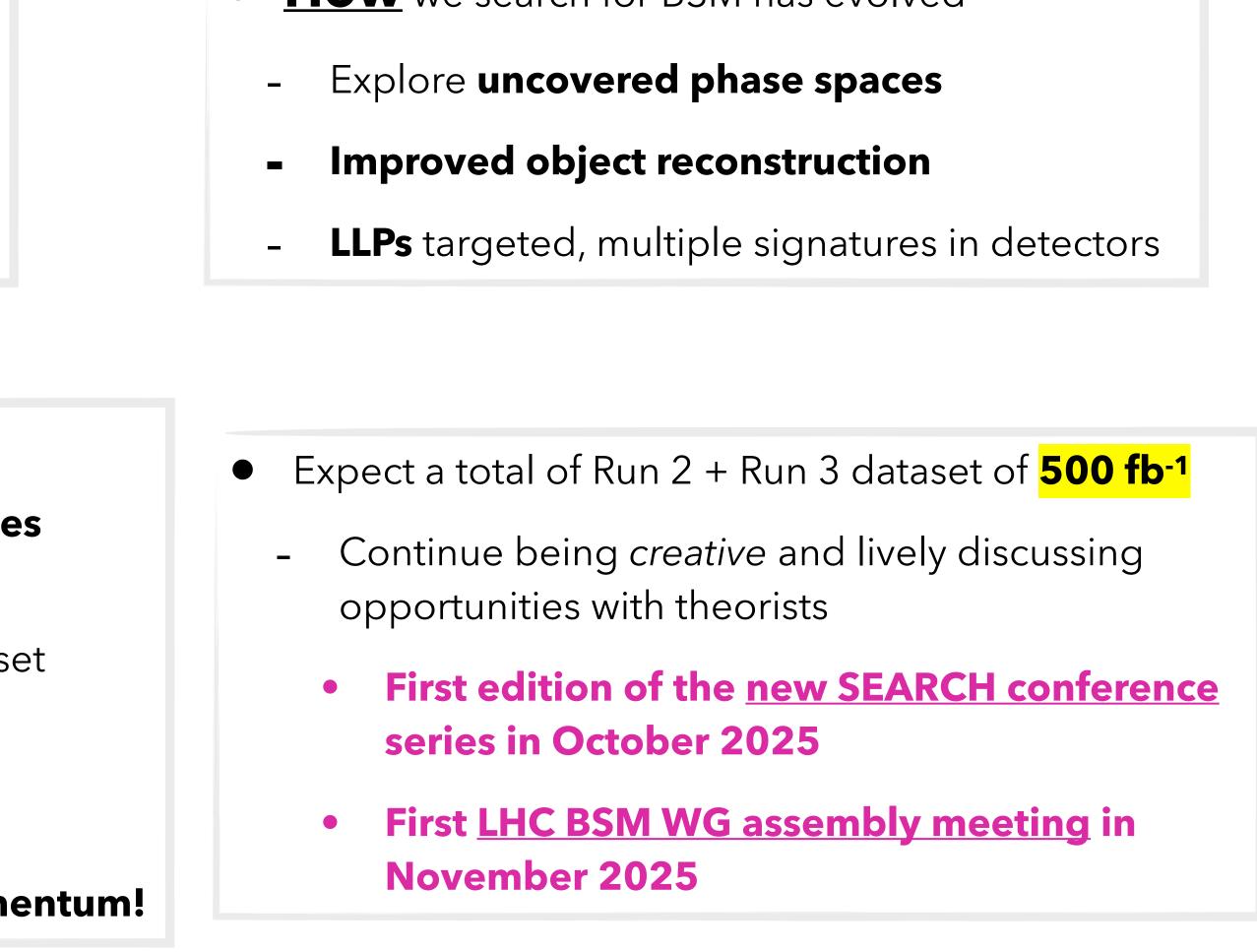


Conclusions

- What we search for has evolved
 - Investigate **new models** (more complete, less vanilla)
 - The **Dark Sector** is in the spotlight! Many interesting signatures to explore

- We continue in **discovery-mode**
 - High priority to follow up with Run 3 dataset on **excesses** observed with Run 2 dataset (+ reanalysing Run 2)
 - Without disregarding **legacy** searches with Run 3 dataset -
- Run 3 dataset only shyly used in recent searches
 - It takes time to understand thoroughly new dataset _
 - New results with partial Run 3 dataset gaining momentum!



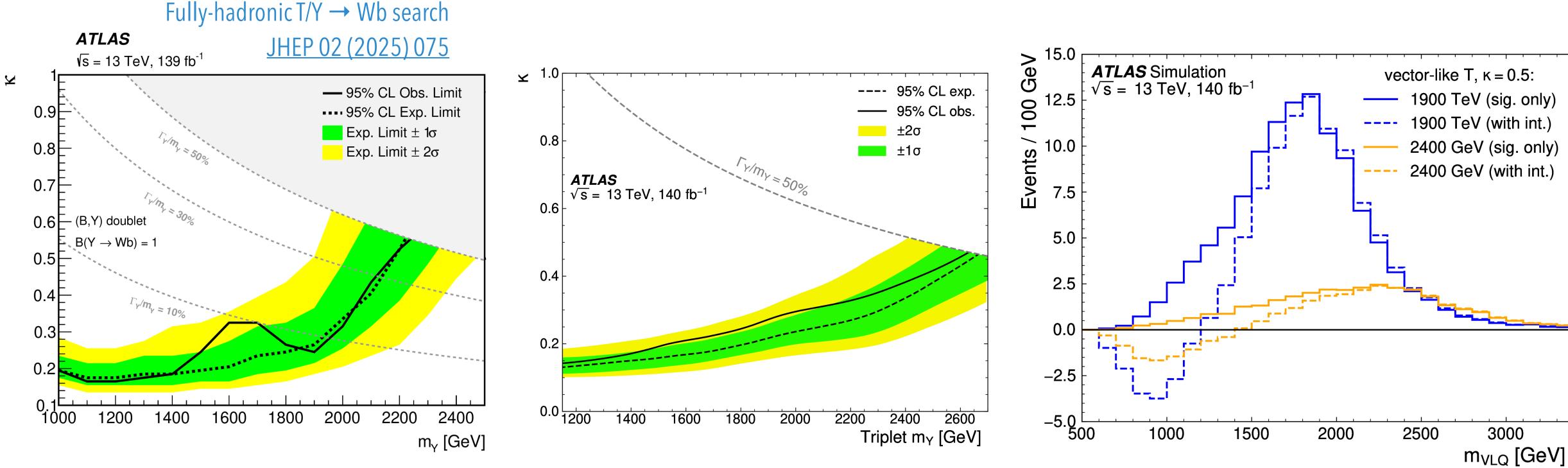








$\bigvee LQ: T/Y \rightarrow Wb(1\ell)$





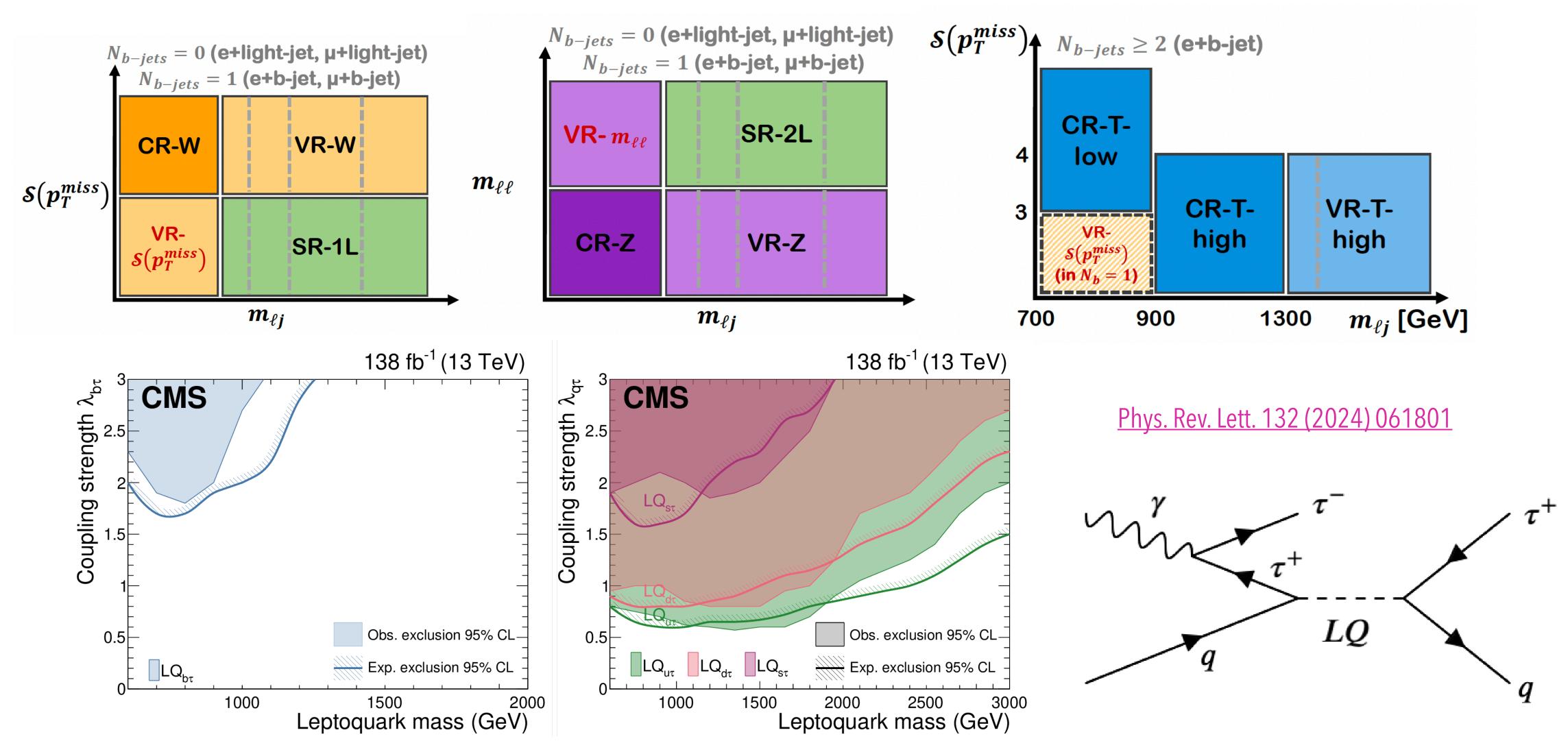






Resonant s-channel LQ

example CRs and VRs: e + b-jet









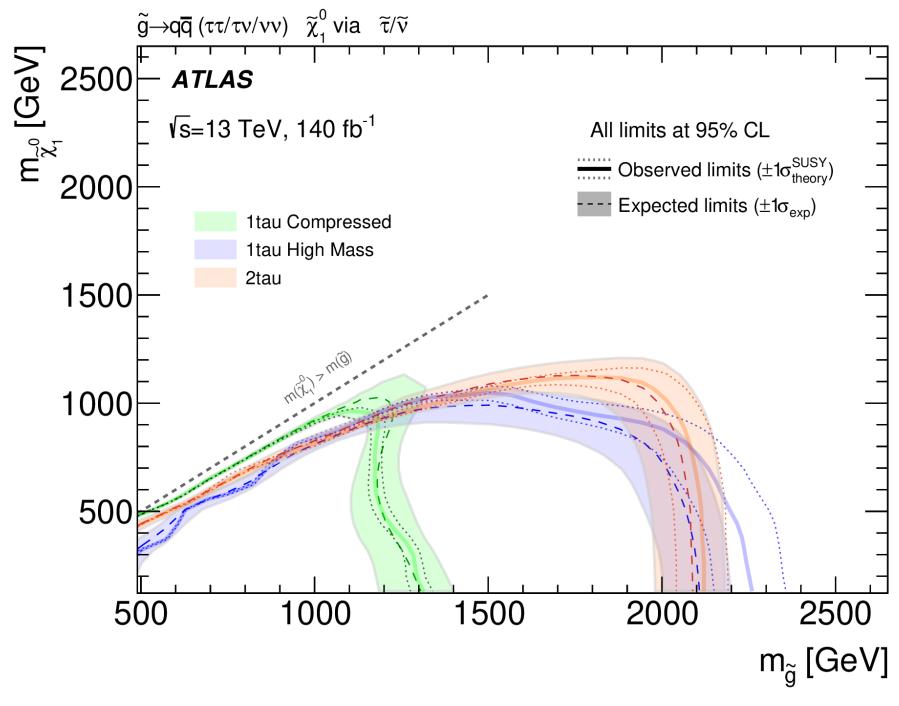
RPC squarks & gluinos: τ+E_Tmiss

		Compre	essed SR	High M	lass SR	TwoTau SR
	Channel	1tau0lep	1tau1lep	1tau0lep	1tau1lep	2ταυ
	$N_e + N_\mu$	= 0	≥ 1	= 0	≥ 1	_
	$N_{ au}$		=	1		2
	$E_{\rm T}^{\rm miss}$ [GeV]		> 4	100		> 200
	$H_{\rm T}$ [GeV]	-	-		000	> 800
	N _{jets}		2		3	≥ 3
	$p_{\mathrm{T}}^{ au_1}$ [GeV] $m_{\mathrm{T}}^{ au_1}$ [GeV]		45		45	—
	$m_{\mathrm{T}}^{\prime_{1}} [\mathrm{GeV}]$	> 80	_	> 250	> 120	_
	$m_{\mathrm{T}}^{\hat{\tau}_1} + m_{\mathrm{T}}^{\ell_1} [\text{GeV}]$ $m_{\mathrm{T}}^{\hat{\tau}_1} + m_{\mathrm{T}}^{\hat{\tau}_2} [\text{GeV}]$	-	> 350	—	> 350	—
	$m_{\rm T}^{\tau_1} + m_{\rm T}^{\tau_2} [{\rm GeV}]$	_	_	—	_	> 150
2500 <i>ATLAS</i> √s=13 TeV, 140 fb ⁻¹ 2000 1tau0lep 1tau1lep 2tau 1000	All limits at 95 Observed line Expected line	mits (±1 $\sigma_{\text{theory}}^{\text{SUSY}}$)	- - - - - - - - - - - - - - - - - - -	2500 – ATL	t/τν/νν) $\tilde{\chi}_{1}^{0}$ via AS 3 TeV, 140 fb ⁻ 1tau Compress 1tau High Mass 2tau	1 sed
500 500 1000	1500 2000	2500 m _g [Ge\		500	<u> </u>	1500

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<u>CERN-EP-2025-132</u>, submitted to EPJC

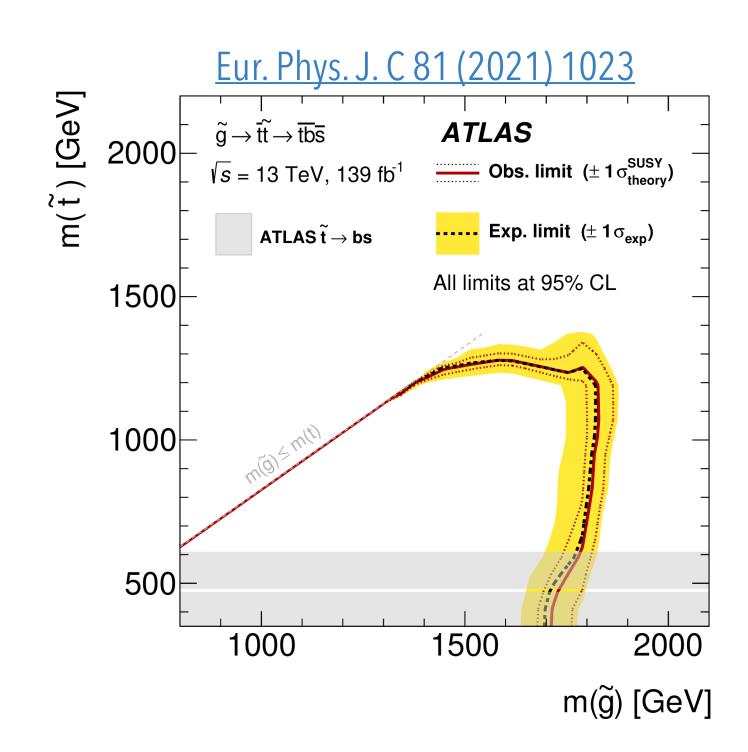




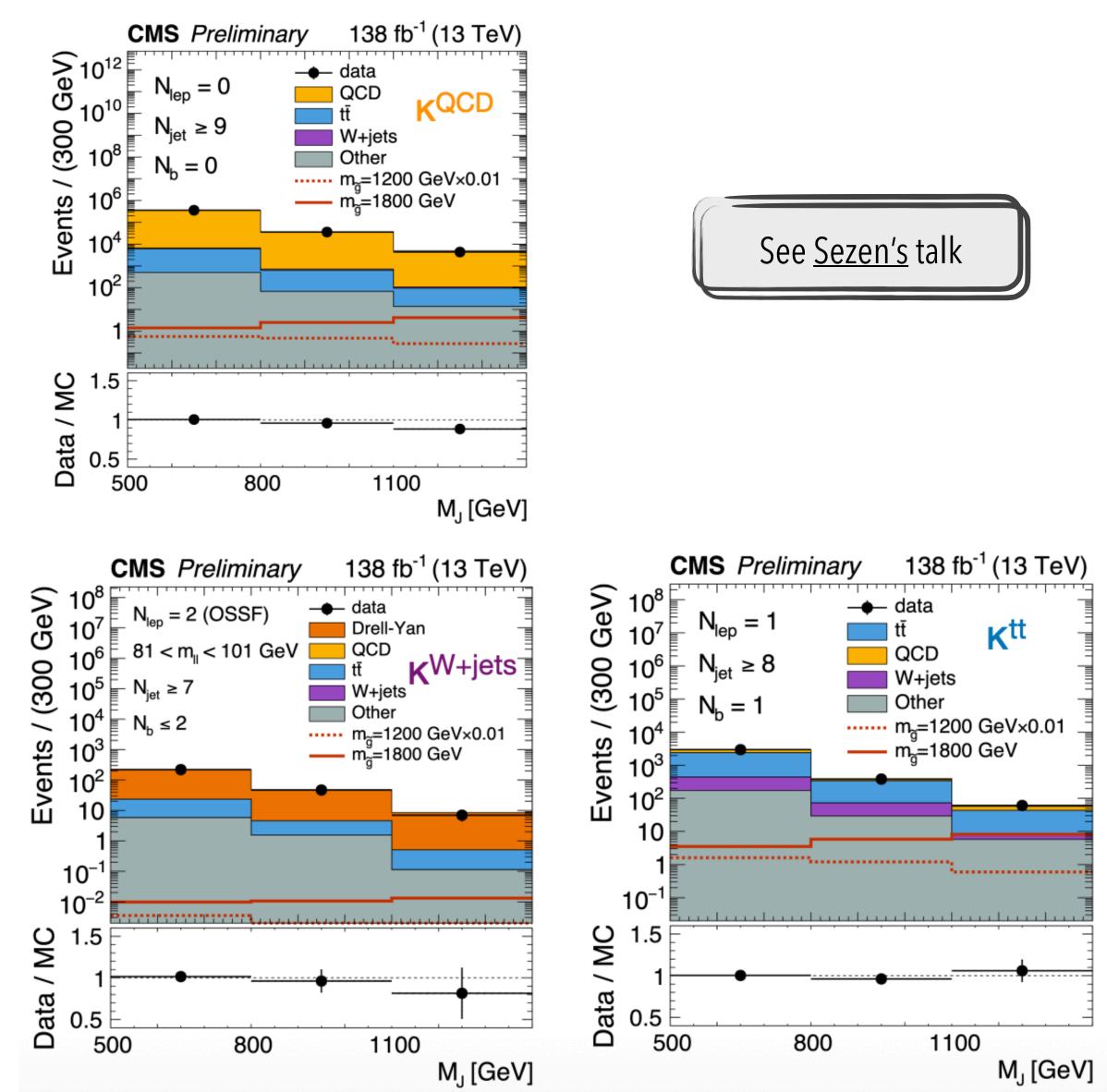




RPV SUSY 12 + multi-(b)jets



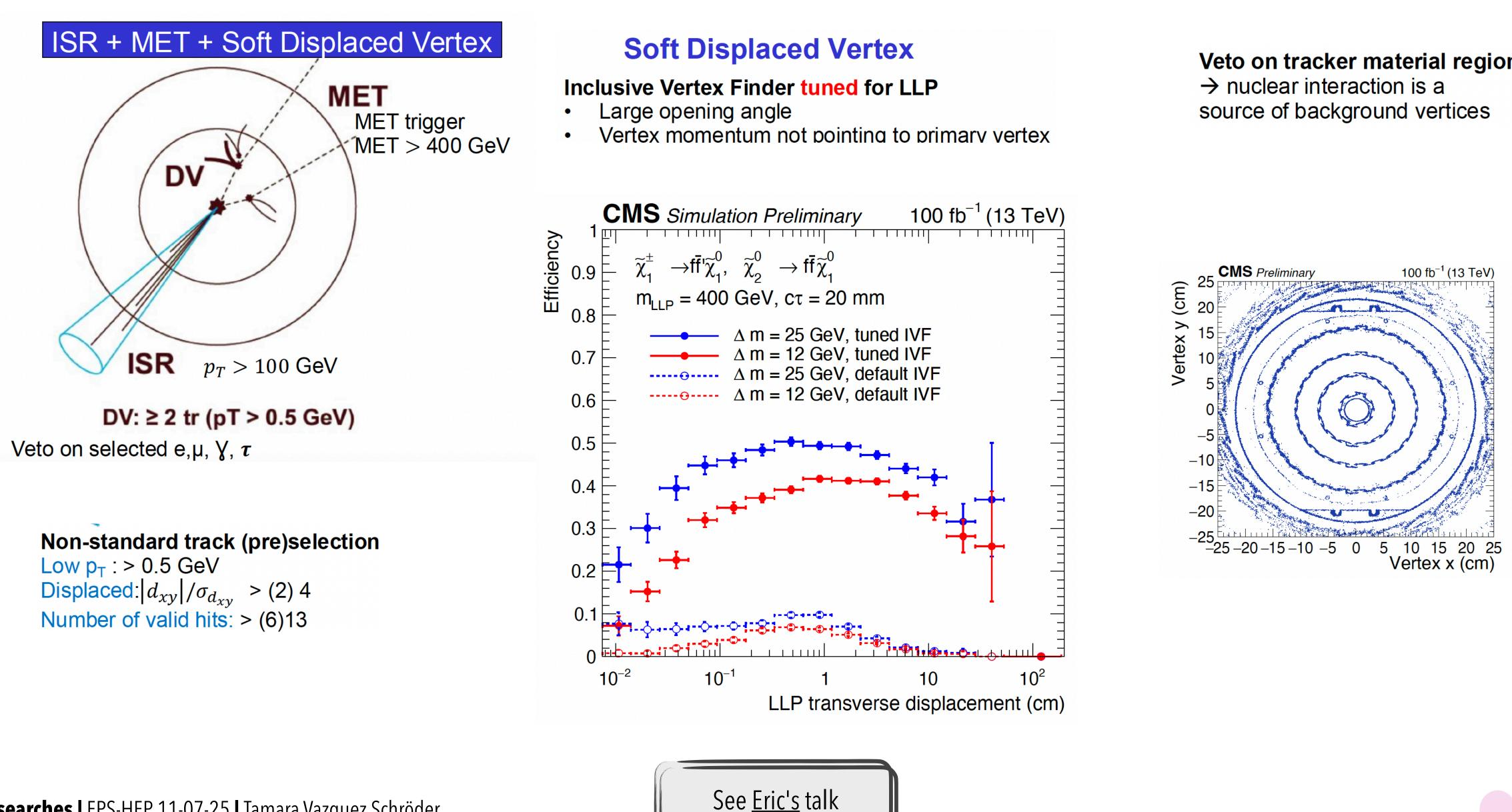
Data / MC 10⁸ Events / (300 GeV) 10⁷ 10⁶ 10⁵ 10⁴ 10³ 10² 10 10-10⁻² Data / WC 0.5 0 50



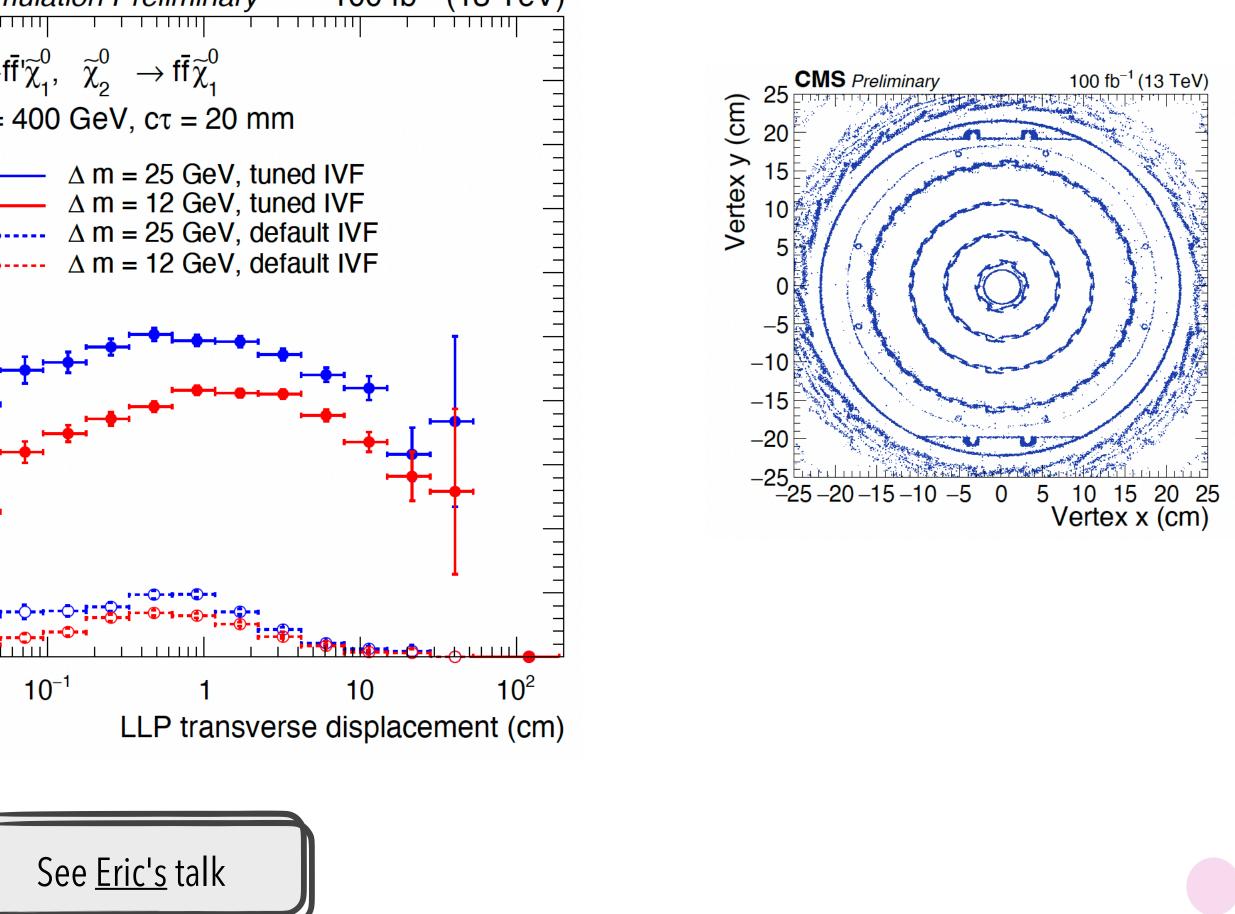




SUSY co-annihilation with LLP



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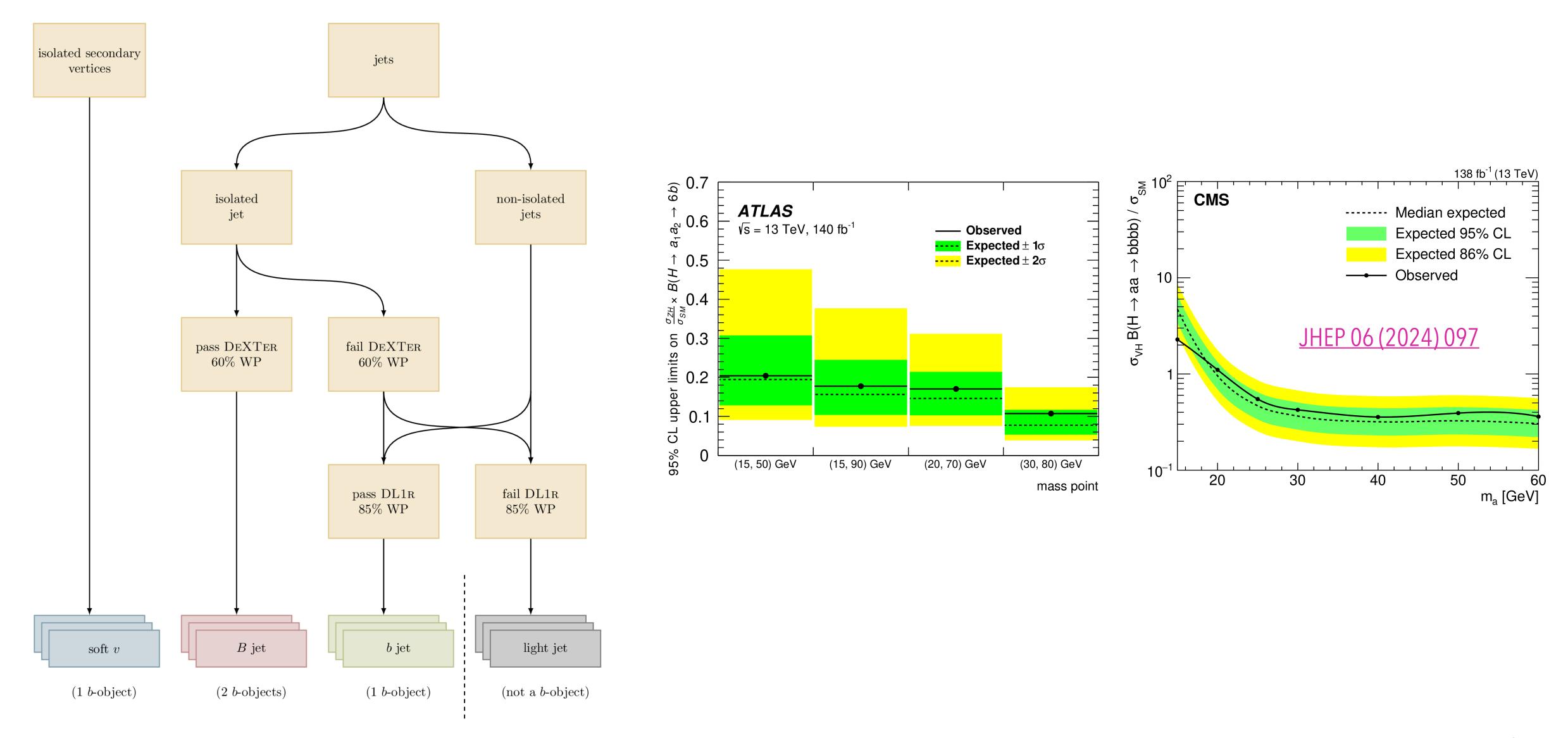






Veto on tracker material region:

 $ZH (H \rightarrow aa \rightarrow 4b/6b)$



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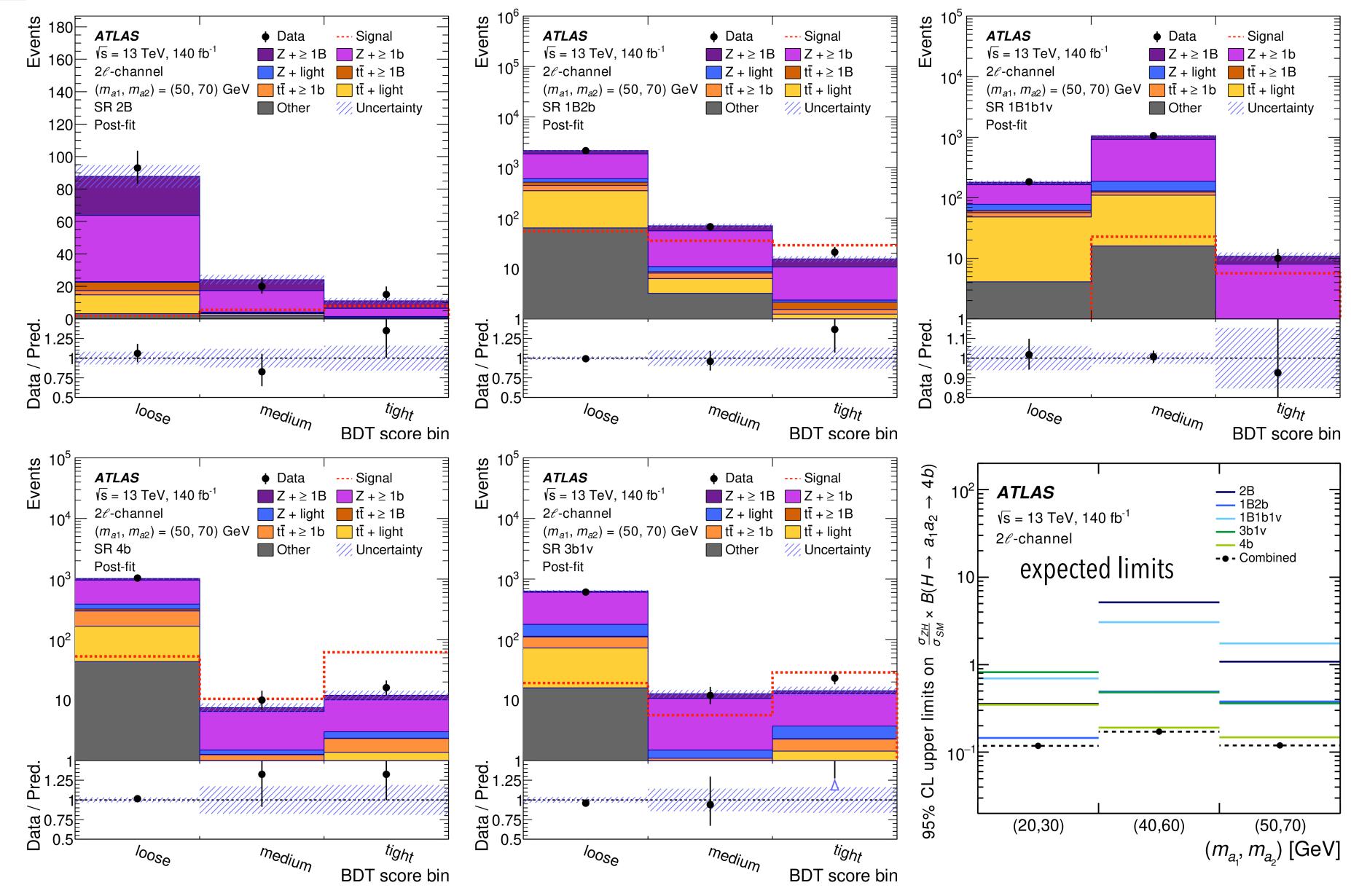
CERN-EP-2025-121, submitted to PRD







$ZH (H \rightarrow aa \rightarrow 4b/6b)$



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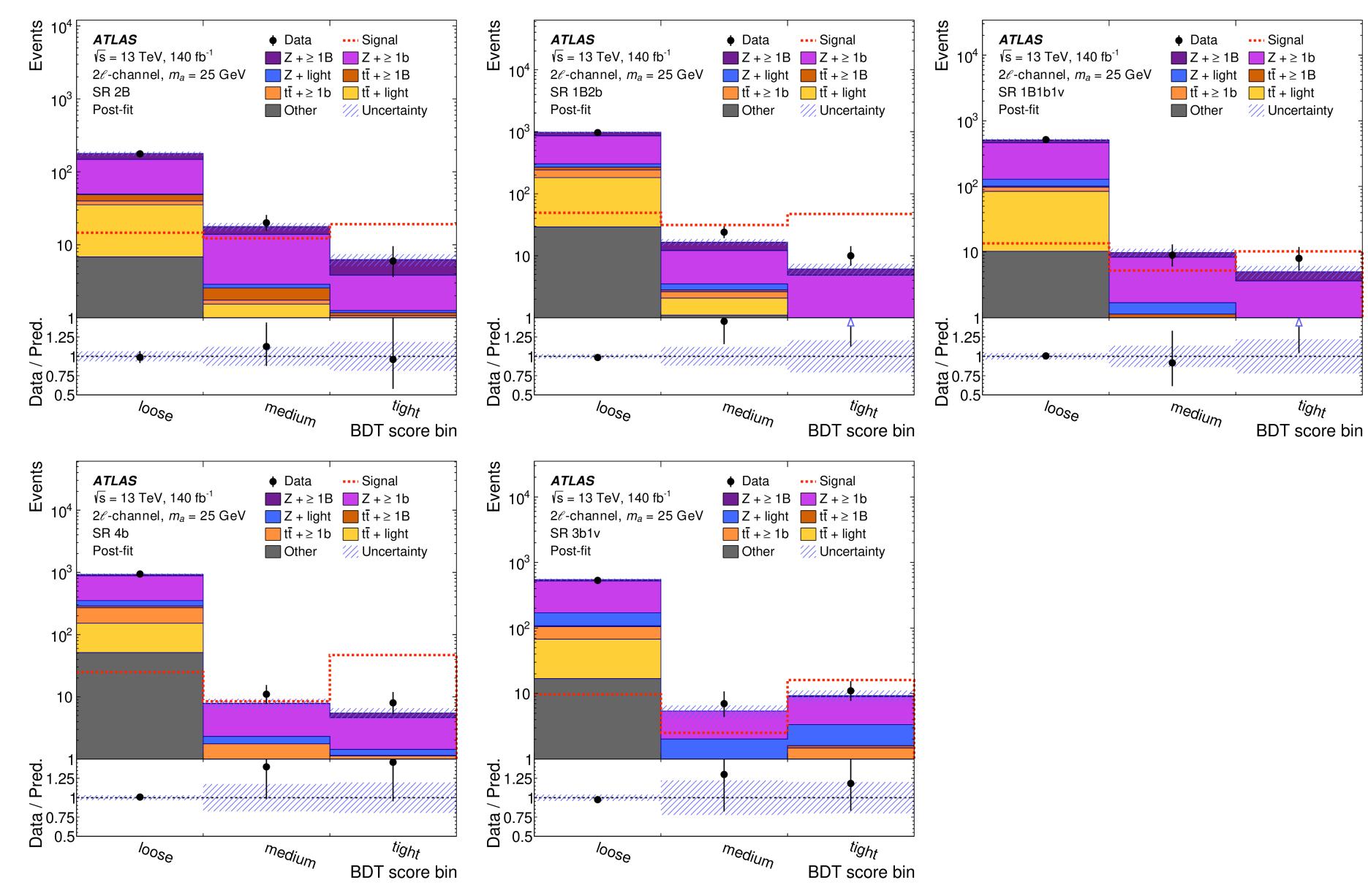
CERN-EP-2025-121, submitted to PRD







$ZH (H \rightarrow aa \rightarrow 4b/6b)$



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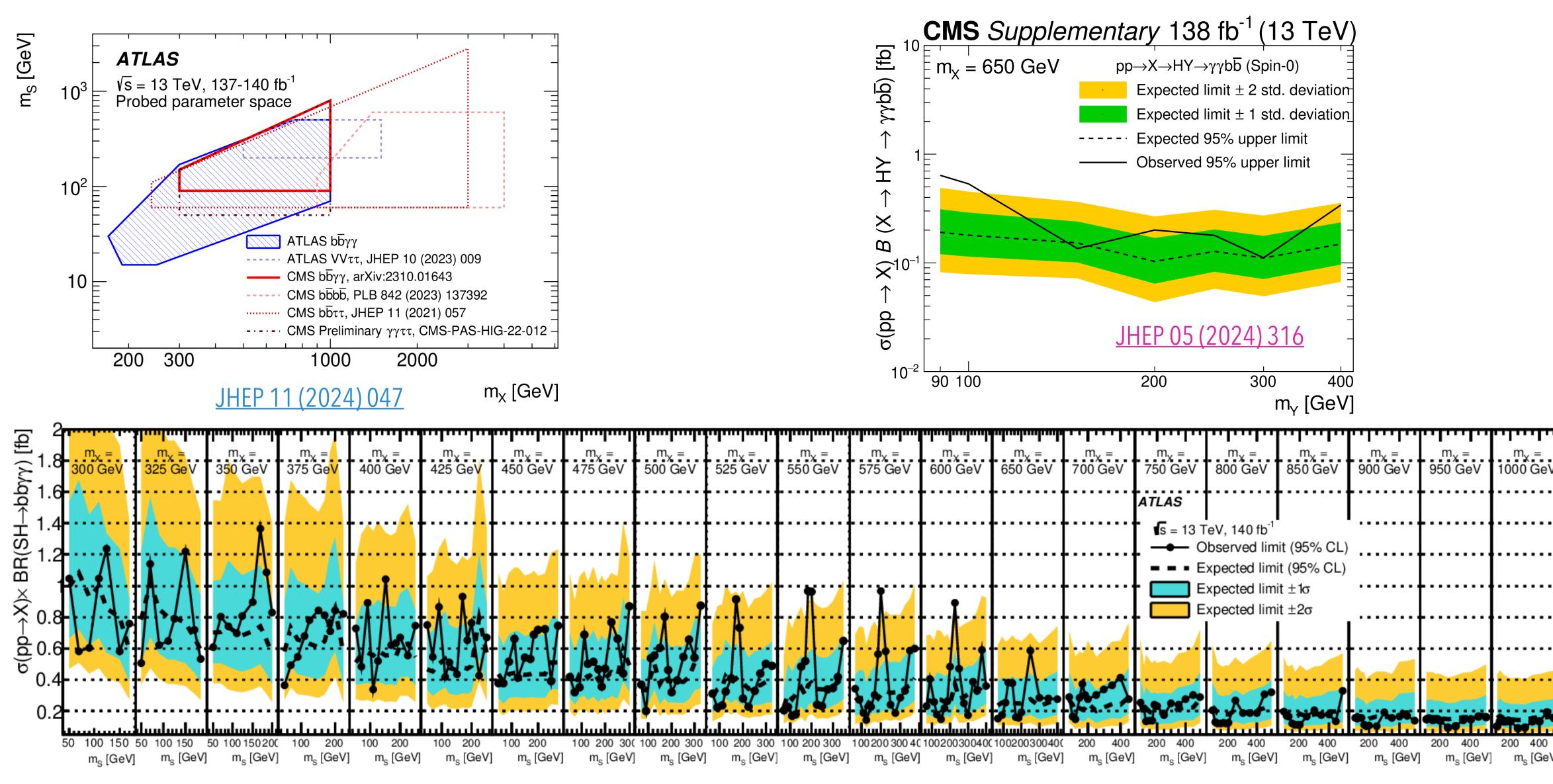
CERN-EP-2025-121, submitted to PRD





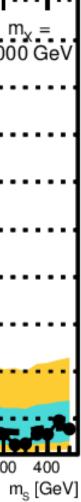














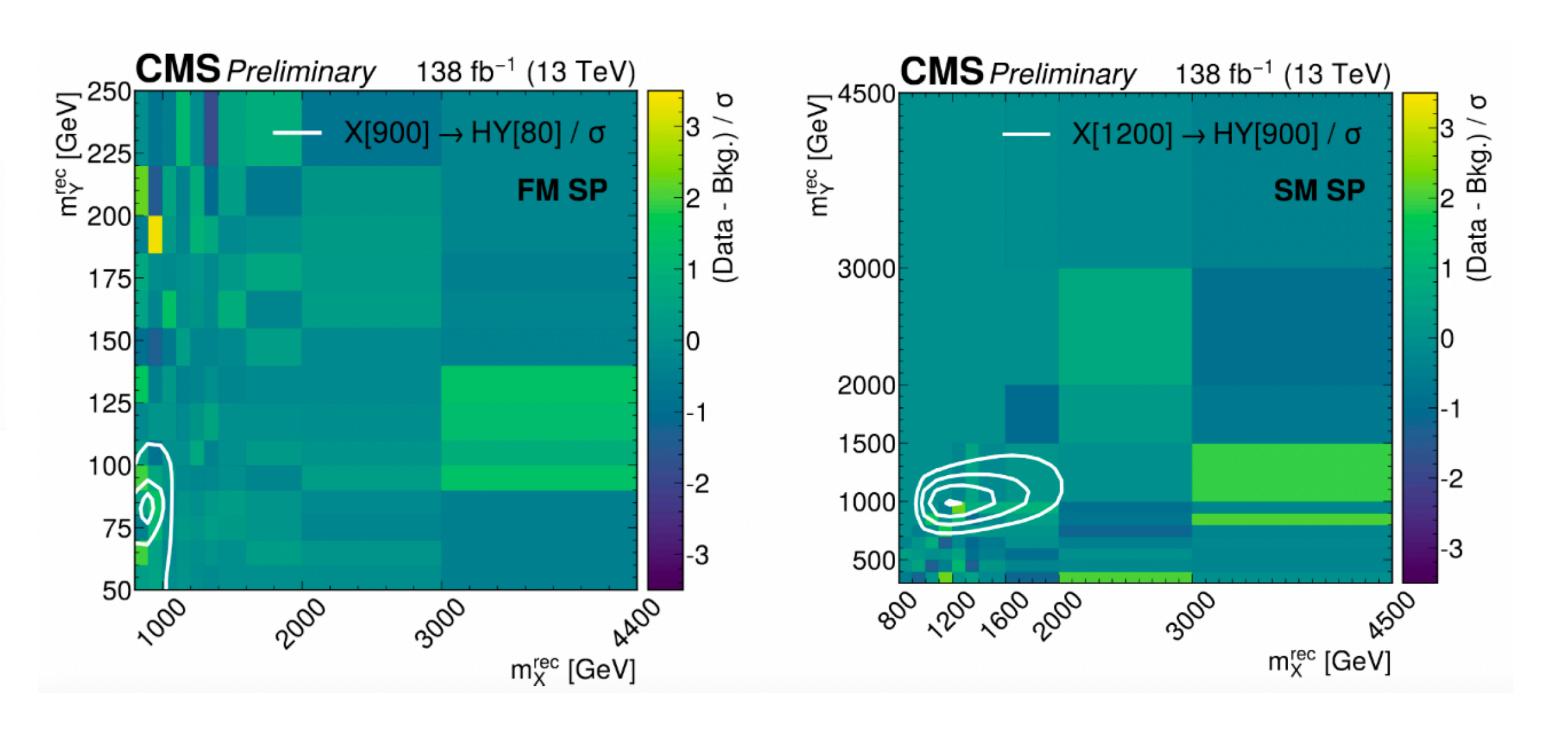
$\rightarrow YH \rightarrow VV(4q)bb$

The analysis exploits state-of-the-art substructure techniques and taggers to identify boosted final states:

- ✓ **PARTICLENET** jet tagger for $H \rightarrow b\bar{b}$ and $V \rightarrow q\bar{q}$: the leading graph-based tagger in CMS [PhysRevD.101.056019]
- ✓ PART jet tagger for $Y \rightarrow VV \rightarrow 4q$: novel attention-based "particle transformer" [arXiv:2202.03772]

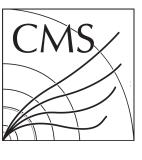
Data-driven background prediction:

- Signal (SP, SF) and Validation (VP, VF) regions are defined, with Pass and Fail Modes to predict background in a data-driven way.
- [QCD prediction in SP] = [Data in SF] $\times R(m_X, m_Y)$
 - $R(m_X, m_Y)$ parametrized as 2D Bernstein polynomials



B2G-23-007

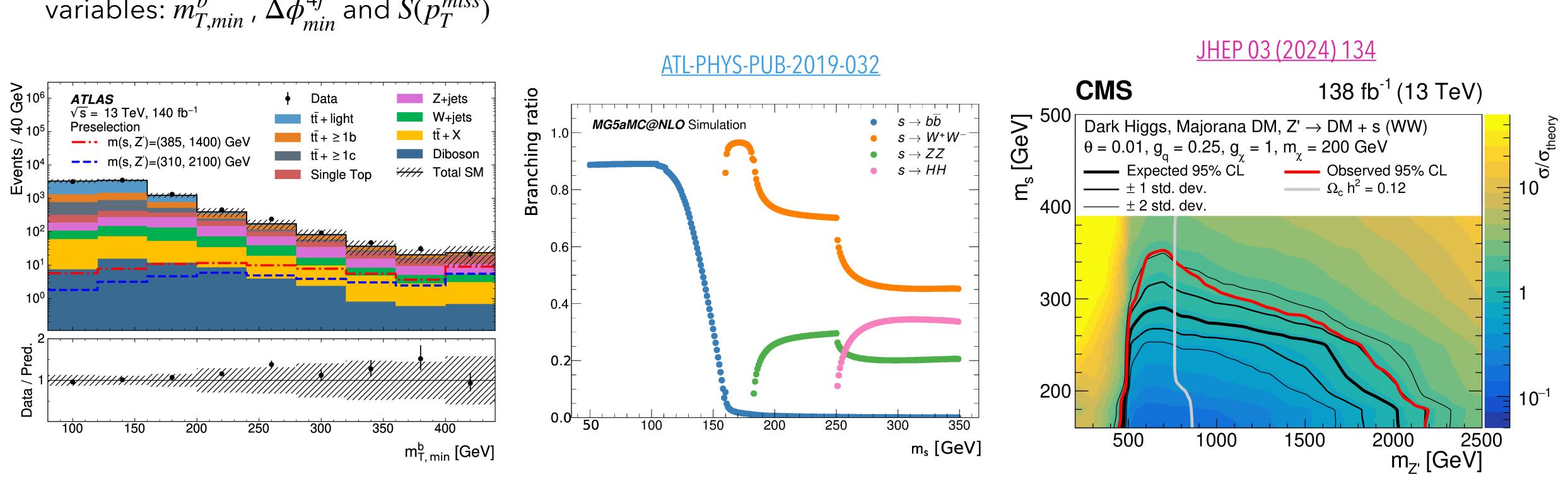
See <u>Ilias'</u> talk





Dark Higgs, multi-b + p_T^{miss}

selections made on p_T^{miss}-based variables: $m^b_{T,min}$, $\Delta \phi^{4j}_{min}$ and $S(p_T^{miss})$



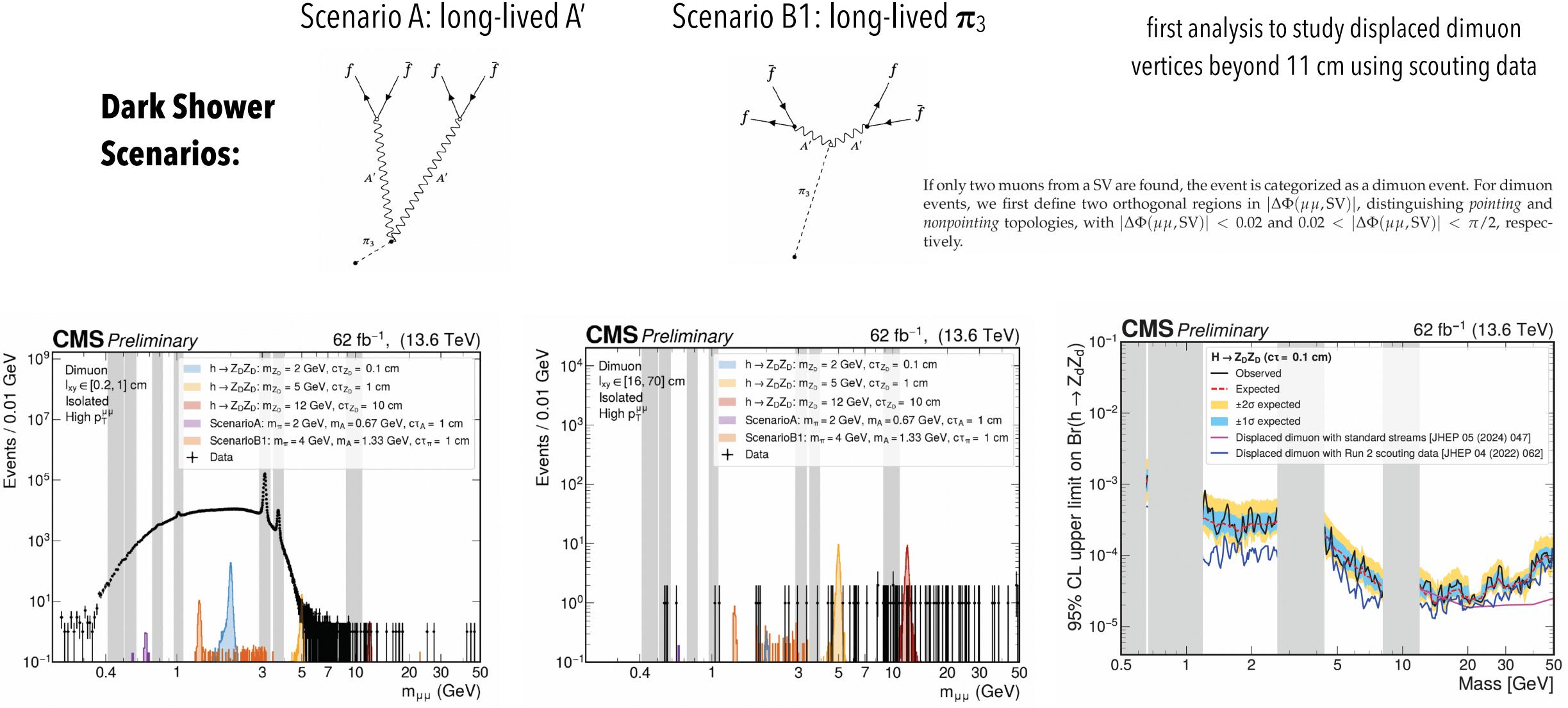
$$m_{\mathrm{T,min}}^{b} = \min_{1 \le i \le 3} \sqrt{(p_{\mathrm{T}}(b_{i}) + p_{\mathrm{T}}^{\mathrm{miss}})^{2} - (p_{\mathrm{x}}(b_{i}) + p_{\mathrm{x}}^{\mathrm{miss}})^{2} - (p_{\mathrm{y}}(b_{i}) + p_{\mathrm{y}}^{\mathrm{miss}})^{2}}$$







Dark Photon LLP to µ



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EXO-24-016



Scenario B1: long-lived π_3

first analysis to study displaced dimuon









Table 2: The LLP triggers and their total rates at the HLT in Run 3, calculated from 2024 data for an instantaneous luminosity of 2.1×10^{34} cm⁻²s⁻¹, with a mean PU of 63.6. Triggers implemented for the first time in Run 3 are indicated by a dagger (⁺). Rate values in parentheses correspond to the parked data rates; all others are standard data rates except for dimuon scouting. Nearly all rates shown have a statistical uncertainty of less than 1 Hz. "Disp." is used as an abbreviation for "displaced" and "req." is used as an abbreviation for "requirement". The terms used in this table are explained in the corresponding subsection within Section 6.

Triggered signature	Trigger description	HLT rate [Hz]
Disappearing track	$p_{\rm T}^{\rm miss}$ > 105 GeV + \geq 1 isolated track ($p_{\rm T}$ > 50 GeV)	4
Disp. tau	$ \begin{split} &\geq 2 \text{ disp. } \tau_{\text{h}} \ (p_{\text{T}} > 32 \text{GeV}, d_0 > 0.005 \text{cm})^{\dagger} \\ &\geq 1 \text{ disp. } \tau_{\text{h}} \ (p_{\text{T}} > 24 \text{GeV}) + \geq 1 \mu \ (p_{\text{T}} > 24 \text{GeV})^{\dagger} \\ &\geq 1 \text{ disp. } \tau_{\text{h}} \ (p_{\text{T}} > 34 \text{GeV}) + \geq 1 \text{e} \ (p_{\text{T}} > 34 \text{GeV})^{\dagger} \end{split}$	36
Disp. jet	$ \begin{split} &\geq 2 \text{ jet } (p_{\mathrm{T}} > 40 \mathrm{GeV}, \text{ inclusive tagging req.}) + H_{\mathrm{T}} > 430 \mathrm{GeV} \\ &\geq 2 \text{ jet } (p_{\mathrm{T}} > 40 \mathrm{GeV}, \text{ disp. tagging req.}) \\ &+ H_{\mathrm{T}} > 240 \mathrm{GeV} + \geq 1 \mathrm{L1} \mu \; (p_{\mathrm{T}} > 6 \mathrm{GeV}) \end{split} $	53 (163)
HCAL-based disp. and delayed jet	\geq 2 jet ($p_{\rm T}$ > 40 GeV, displ. tagging req.) + $H_{\rm T}$ > 170 GeV ⁺ \geq 2 jet ($p_{\rm T}$ > 40 GeV, inclusive. tagging req.) + $H_{\rm T}$ > 200 GeV ⁺ \geq 1 jet ($p_{\rm T}$ > 60 GeV, neutral hadron energy fraction >0.7) + $H_{\rm T}$ > 200 GeV ⁺	35
ECAL-based delayed jet	\geq 1 inclusive and trackless jet ⁺	37 (77)
Delayed diphoton	\geq 2 ECAL superclusters (time >1 ns) ⁺	15
Disp. photon + $H_{\rm T}$	$\geq 1 \gamma (p_{\mathrm{T}} > 60 \mathrm{GeV}) + \mathrm{PF} H_{\mathrm{T}} > 350 \mathrm{GeV}$	12
Disp. single and dimuon	$ \geq 2 \text{ L2 } \mu \ (p_{\text{T}} > 10 \text{ GeV}, d_0 > 1 \text{ cm})^{\dagger} \\ \geq 2 \text{ L3 } \mu \ (p_{\text{T}} > 16, 10 \text{ GeV}, d_0 > 0.01 \text{ cm})^{\dagger} \\ \geq 2 \text{ L2 } \mu \ (p_{\text{T}} > 23 \text{ GeV}) \\ \geq 1 \text{ L2 } \mu \ (p_{\text{T}} > 50 \text{ GeV}, d_0 > 1 \text{ cm})^{\dagger} \\ \geq 1 \text{ L3 } \mu \ (p_{\text{T}} > 30 \text{ GeV}, d_0 > 0.01 \text{ cm})^{\dagger} $	165

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EXO-23-016

L	C	-		

Double disp. L3 muon	\geq 2 L3 μ ($p_{\rm T}$ > 43 GeV)	2
Disp. L3 muon+photon	$ \geq 1 \text{ L3 } \mu (p_{\text{T}} > 43 \text{ GeV}) + \gamma (p_{\text{T}} > 43 \text{ GeV}) \\ \geq 1 \text{ L3 } \mu (p_{\text{T}} > 38 \text{ GeV}, d_0 > 1 \text{ cm}) + \gamma (p_{\text{T}} > 38 \text{ GeV}) $	5
Dimuon scouting	\geq 2 scouting μ ($p_{\rm T}$ > 3 GeV)	4200
MDS in CSCs	\geq 1 CSC cluster (\geq 200/500 hits in outer/inner rings) ⁺ \geq 2 CSC clusters (\geq 75 hits) ⁺	14
MDS in CSCs + X	$ \geq 1 \operatorname{CSC} \operatorname{cluster} (\geq 100 \text{ hits}) + \geq 1 \operatorname{e} (p_{\mathrm{T}} > 5 \operatorname{GeV})^{\dagger} \\ \geq 1 \operatorname{CSC} \operatorname{cluster} (\geq 100 \text{ hits}) + \geq 1 \operatorname{L3} \mu (p_{\mathrm{T}} > 5 \operatorname{GeV})^{\dagger} \\ \geq 1 \operatorname{CSC} \operatorname{cluster} (\geq 100 \text{ hits}) + \geq 1 \tau_{\mathrm{h}} (p_{\mathrm{T}} > 10 \operatorname{GeV})^{\dagger} \\ \geq 1 \operatorname{CSC} \operatorname{cluster} (\geq 50 \text{ hits}) + \geq 1 \gamma (p_{\mathrm{T}} > 20 \operatorname{GeV})^{\dagger} $	14
MDS in DTs	L1 $p_T^{miss} > 150 \text{ GeV} + \ge 1 \text{ DT cluster} (\ge 50 \text{ hits})^+$ $\ge 1 \text{ L1 CSC cluster} + \ge 1 \text{ DT cluster} (\ge 50 \text{ hits})^+$	9
Jet No-BPTX	\geq 1 out-of-time jet ($E > 60 \text{GeV}$)	1
Muon No-BPTX	\geq 1 out-of-time L2 μ ($p_{\rm T}$ > 40 GeV)	7







Summary: ATLAS Heavy Particles Searches

Status: March 2023					$\int \mathcal{L} dt = (3.6 - 139) \text{ fb}^{-1}$	√ <i>s</i> = 13 TeV
Model	ℓ , γ Jets†	E_{T}^{miss}	∫£ dt[fb	Limit	5	Reference
ADD $G_{KK} + g/q$ ADD non-resonant $\gamma\gamma$ ADD QBH ADD BH multijet RS1 $G_{KK} \rightarrow \gamma\gamma$ Bulk RS $G_{KK} \rightarrow WW/ZZ$ Bulk RS $g_{KK} \rightarrow tt$ 2UED / RPP	$\begin{array}{cccccccccccccccccccccccccccccccccccc$		139 36.7 139 3.6 139 36.1 36.1 36.1	ass 2.3 TeV	11.2 TeV $n = 2$ 8.6 TeV $n = 3$ HLZ NLO 9.4 TeV $n = 6$ 9.55 TeV $n = 6$, $M_D = 3$ TeV, rot BH $k/\overline{M}_{Pl} = 0.1$ $k/\overline{M}_{Pl} = 1.0$ TeV $\Gamma/m = 15\%$ Tier (1,1), $\mathcal{B}(A^{(1,1)} \rightarrow tt) = 1$	2102.10874 1707.04147 1910.08447 1512.02586 2102.13405 1808.02380 1804.10823 1803.09678
SSM $Z' \rightarrow \ell\ell$ SSM $Z' \rightarrow \tau\tau$ Leptophobic $Z' \rightarrow bb$ Leptophobic $Z' \rightarrow tt$ SSM $W' \rightarrow \ell\nu$ SSM $W' \rightarrow \tau\nu$ SSM $W' \rightarrow tb$ HVT $W' \rightarrow WZ$ model B HVT $W' \rightarrow WZ \rightarrow \ell\nu \ell'\ell'$ mod HVT $Z' \rightarrow WW$ model B LRSM $W_R \rightarrow \mu N_R$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Yes Yes	139 36.1 36.1 139 139 139 139 139 139 139 139 80	ass ass ass 4 ass 24 ass 340 GeV	5.1 TeV 1 TeV 6.0 TeV 5.0 TeV 5.4 TeV .3 TeV $g_V = 3$ $g_V = 3$ $g_V = 3$ $m(N_R) = 0.5$ TeV, $g_L = g_R$	1903.06248 1709.07242 1805.09299 2005.05138 1906.05609 ATLAS-CONF-2021-025 ATLAS-CONF-2021-043 2004.14636 2207.03925 2004.14636 1904.12679
CI qqqq CI ℓℓqq CI eebs CI μμbs CI tttt	$ \begin{array}{cccc} - & 2 j \\ 2 e, \mu & - \\ 2 e & 1 b \\ 2 \mu & 1 b \\ \geq 1 e, \mu & \geq 1 b, \geq 1 \end{array} $	– – – j Yes	37.0 139 139 139 36.1	1.8 TeV 2.0 TeV 2.57 TeV	$egin{array}{c c c c c c c c c c c c c c c c c c c $	L 1703.09127 2006.12946 2105.13847 2105.13847 1811.02305
Axial-vector med. (Dirac DM) Pseudo-scalar med. (Dirac DM) Vector med. Z'-2HDM (Dirac D Pseudo-scalar med. 2HDM+a		– Yes Yes	139 139 139 139	3.8 376 GeV 3.0 TeV 800 GeV	TeV $g_q = 0.25, g_{\chi} = 1, m(\chi) = 10 \text{ TeV}$ $g_q = 1, g_{\chi} = 1, m(\chi) = 1 \text{ GeV}$ $\tan \beta = 1, g_{\chi} = 0.8, m(\chi) = 100 \text{ GeV}$ $\tan \beta = 1, g_{\chi} = 1, m(\chi) = 10 \text{ GeV}$	ATL-PHYS-PUB-2022-03 2102.10874 2108.13391 ATLAS-CONF-2021-03
Scalar LQ 1 st gen Scalar LQ 2 nd gen Scalar LQ 3 rd gen Scalar LQ 3 rd gen Scalar LQ 3 rd gen Scalar LQ 3 rd gen Vector LQ mix gen Vector LQ 3 rd gen	$\begin{array}{cccc} 2 \ e & \geq 2 \ j \\ 2 \ \mu & \geq 2 \ j \\ 1 \ \tau & 2 \ b \\ 0 \ e, \ \mu & \geq 2 \ j, \geq 2 \ l \\ \geq 2 \ e, \ \mu, \geq 1 \ \tau & \geq 1 \ j, \geq 1 \ l \\ 0 \ e, \ \mu, \geq 1 \ \tau & 0 - 2 \ j, 2 \\ multi-channel \geq 1 \ j, \geq 1 \ l \\ 2 \ e, \ \mu, \ \tau & \geq 1 \ b \end{array}$	o – O Yes	139 139 139 139 139 139 139 139	Iss1.8 TeVIss1.7 TeVIss1.49 TeVIss1.49 TeVIss1.24 TeVIss1.43 TeVIss1.26 TeVIss1.26 TeVIss1.96 TeV	$\begin{split} \beta &= 1\\ \beta &= 1\\ \mathcal{B}(\mathrm{LQ}_3^u \to b\tau) &= 1\\ \mathcal{B}(\mathrm{LQ}_3^u \to t\nu) &= 1\\ \mathcal{B}(\mathrm{LQ}_3^d \to t\tau) &= 1\\ \mathcal{B}(\mathrm{LQ}_3^d \to b\nu) &= 1\\ \mathcal{B}(\tilde{U}_1 \to t\mu) &= 1, \text{ Y-M coupl.}\\ \mathcal{B}(\mathrm{LQ}_3^V \to b\tau) &= 1, \text{ Y-M coupl.} \end{split}$	2006.05872 2006.05872 2303.01294 2004.14060 2101.11582 2101.12527 ATLAS-CONF-2022-052 2303.01294
VLQ $TT \rightarrow Zt + X$ VLQ $BB \rightarrow Wt/Zb + X$ VLQ $T_{5/3}T_{5/3} T_{5/3} \rightarrow Wt + X$ VLQ $T \rightarrow Ht/Zt$ VLQ $Y \rightarrow Wb$ VLQ $B \rightarrow Hb$ VLL $\tau' \rightarrow Z\tau/H\tau$	$\begin{array}{c c} 2e/2\mu/\geq 3e, \mu \geq 1 \ \text{b}, \geq 1 \\ \text{multi-channel} \\ 2(\text{SS})/\geq 3 \ e, \mu \geq 1 \ \text{b}, \geq 1 \\ 1 \ e, \mu \geq 1 \ \text{b}, \geq 3 \\ 1 \ e, \mu \geq 1 \ \text{b}, \geq 1 \\ 0 \ e, \mu \geq 2\text{b}, \geq 1\text{j}, \geq 1 \\ \text{multi-channel} \geq 1 \ \text{j} \end{array}$	Yes Yes Yes	139 36.1 36.1 139 36.1 139 139	s 1.46 TeV s 1.34 TeV hass 1.64 TeV s 1.64 TeV s 1.8 TeV s 2.0 TeV s 898 GeV	SU(2) doublet SU(2) doublet $\mathcal{B}(T_{5/3} \rightarrow Wt) = 1, c(T_{5/3}Wt)$ SU(2) singlet, $\kappa_T = 0.5$ $\mathcal{B}(Y \rightarrow Wb) = 1, c_R(Wb) = 1$ SU(2) doublet, $\kappa_B = 0.3$ SU(2) doublet	= 1 2210.15413 1808.02343 1807.11883 ATLAS-CONF-2021-04 1812.07343 ATLAS-CONF-2021-01 2303.05441
Excited quark $q^* \rightarrow qg$ Excited quark $q^* \rightarrow q\gamma$ Excited quark $b^* \rightarrow bg$ Excited lepton τ^*	- 2j 1γ 1j - 1b, 1j 2τ ≥2j	_ _ _ _	139 36.7 139 139	ss and a second	6.7 TeV only u^* and d^* , $\Lambda = m(q^*)$ 5.3 TeV only u^* and d^* , $\Lambda = m(q^*)$ V $\Lambda = 4.6$ TeV	1910.08447 1709.10440 1910.08447 2303.09444
Type III Seesaw LRSM Majorana v Higgs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ Higgs triplet $H^{\pm\pm} \rightarrow \ell \ell$ Multi-charged particles Magnetic monopoles	$\begin{array}{cccc} 2,3,4 \ e,\mu & \geq 2 \ j \\ 2 \ \mu & 2 \ j \\ 2,3,4 \ e,\mu \ (SS) & \text{various} \\ 2,3,4 \ e,\mu \ (SS) & - \\ & - & - \\ & - & - \\ & - & - \end{array}$	Yes _ Yes _ _	139 36.1 139 139 139 34.4	Ass 350 GeV Ass 350 GeV Ass 1.08 TeV Aarged particle mass 1.59 TeV bole mass 2.37 TeV	V $m(W_R) = 4.1 \text{ TeV}, g_L = g_R$ DY production DY production DY production, $ q = 5e$ DY production, $ g = 1g_D$, spin	2202.02039 1809.11105 2101.11961 2211.07505 ATLAS-CONF-2022-03 1/2 1905.10130

*Only a selection of the available mass limits on new states or phenomena is shown. *†Small-radius (large-radius) jets are denoted by the letter j (J).*

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ATL-PHYS-PUB-2023-008







Summary: ATLAS LLP Searches

ATLACI and lived Dertials Secretars* 050/ CL Evaluation

	atus: March 2023								$\int \mathcal{L} dt = 0$	32.8 – 139) fb ⁻¹	<i>√s</i> = 13 Te∖
	Model	Signature	∫£ dt [fl	o ⁻¹]	Lifetir	me limit			-		Reference
	RPV $\widetilde{t} ightarrow \mu q$	displaced vtx + muon	136	t lifetime		ч · · · · · ·		0.003-6.0 r	n <mark>n</mark>	$m(\tilde{t})=1.4$ TeV	2003.11956
	$RPV\tilde{\chi}^0_1 \to ee\nu/e\mu\nu/\mu\mu\nu$	displaced lepton pair	32.8	${ ilde \chi}_1^0$ lifetime			0.003-	1.0 m		$m(ilde{q}){=}$ 1.6 TeV, $m(ilde{\chi}_1^0){=}$ 1.3 TeV	1907.10037
	$RPV \widetilde{\chi}_1^0 o q q q$	displaced vtx + jets	139	${ ilde \chi}_1^{f 0}$ lifetime				0.00135-9	9.0 m	$m({ ilde \chi}_1^0){=}$ 1.0 TeV	2301.13866
	$\operatorname{GGM} \tilde{\chi}_1^0 \to Z \tilde{G}$	displaced dimuon	32.9	${ ilde \chi}_1^{0}$ lifetime				0	.029-18.0 m	$m(ilde{g}){=}$ 1.1 TeV, $m(ilde{\chi}_1^0){=}$ 1.0 TeV	1808.03057
	GMSB	non-pointing or delayed γ	y 139	${ ilde \chi}_1^0$ lifetime				0.24-2.4 m		$m({ ilde \chi}_1^0,{ ilde G})$ = 60, 20 GeV, $\mathcal{B}_{\mathcal{H}}$ = 2%	2209.01029
	GMSB $\tilde{\ell} \to \ell \tilde{G}$	displaced lepton	139	$\widetilde{\ell}$ lifetime			6-750 r	nm		$m(\widetilde{\ell}){=}600~{ m GeV}$	2011.07812
1 000	GMSB $\tilde{\tau} \rightarrow \tau \tilde{G}$	displaced lepton	139	$ ilde{ au}$ lifetime			9-270 mm			$m(ilde{\ell}){=}200~{ m GeV}$	2011.07812
N	AMSB $pp \rightarrow \tilde{\chi}_1^{\pm} \tilde{\chi}_1^0, \tilde{\chi}_1^+ \tilde{\chi}_1^-$	disappearing track	136	${ ilde \chi}_1^{\pm}$ lifetime				0.06-3.06 m		$m({ ilde \chi}_1^{\pm}){=}$ 650 GeV	2201.02472
	AMSB $pp \rightarrow \tilde{\chi}_1^{\pm} \tilde{\chi}_1^0, \tilde{\chi}_1^+ \tilde{\chi}_1^-$	large pixel dE/dx	139	${ ilde \chi}_1^{\pm}$ lifetime			0	.3-30.0 m		$m(ilde{\chi}_1^{\pm}) = 600 ext{GeV}$	2205.06013
	Stealth SUSY	2 MS vertices	36.1	S lifetime			0.1-519 m			$\mathcal{B}(\tilde{g} \rightarrow \tilde{S}g) = 0.1, \ m(\tilde{g}) = 500 \ \text{GeV}$	1811.07370
	Split SUSY	large pixel dE/dx	139	ğ lifetime				> 0.45 m		$m(ilde{g}){=}$ 1.8 TeV, $m(ilde{\chi}_1^0){=}$ 100 GeV	2205.06013
	Split SUSY	displaced vtx + $E_{\rm T}^{\rm miss}$	32.8	g̃ lifetime				0.0	3-13.2 m	$m(ilde{g}){=}$ 1.8 TeV, $m(ilde{\chi}_1^0){=}$ 100 GeV	1710.04901
	Split SUSY	0 ℓ , 2 – 6 jets + E_{T}^{miss}	36.1	ğ lifetime		_	-	0.0-2.1 m		$m(ilde{g}){=}$ 1.8 TeV, $m(ilde{\chi}_1^0){=}$ 100 GeV	ATLAS-CONF-2018-0
	$H \rightarrow s s$	2 MS vertices	139	s lifetime			C	.31-72.4 m		<i>m</i> (<i>s</i>)= 35 GeV	2203.00587
ę	$H \rightarrow s s$	2 low-EMF trackless jets	139	s lifetime				0.19-6.94	m	<i>m</i> (<i>s</i>)= 35 GeV	2203.01009
	VH with $H \rightarrow ss \rightarrow bbbb$	2ℓ + 2 displ. vertices	139	s lifetime		4-85 mm				<i>m</i> (<i>s</i>)= 35 GeV	2107.06092
	FRVZ $H \rightarrow 2\gamma_d + X$	2 μ –jets	139	γ _d lifetime			0.654-939	<mark>) mm</mark>		$m(\gamma_d) =$ 400 MeV	2206.12181
chhiu	FRVZ $H ightarrow 4\gamma_d + X$	2 μ –jets	139	γ_{d} lifetime			2.7-534 mm			$m(\gamma_d) =$ 400 MeV	2206.12181
Ê	$H \rightarrow Z_d Z_d$	displaced dimuon	32.9	Z _d lifetime		0.009-24.0 m				$m(Z_d) = 40 \text{ GeV}$	1808.03057
	$H \rightarrow ZZ_d$ 2	e, μ + low-EMF trackless	jet 36.1	Z _d lifetime			_	0.21-5.2 m		$m(Z_d) = 10 \text{ GeV}$	1811.02542
	$\Phi(200 \text{ GeV}) \rightarrow ss$ lo	w-EMF trk-less jets, MS	vtx 36.1	s lifetime				0.41-51.5 m		$\sigma imes \mathcal{B} =$ 1 pb, $m(s) =$ 50 GeV	1902.03094
ocalar	$\Phi(600 \text{ GeV}) \rightarrow ss$ lo	w-EMF trk-less jets, MS v	vtx 36.1	s lifetime		0.0)4-21.5 m			$\sigma \times \mathcal{B} =$ 1 pb, $m(s) =$ 50 GeV	1902.03094
ñ	$\Phi(1 \text{ TeV}) \rightarrow ss$ lo	w-EMF trk-less jets, MS v	vtx 36.1	s lifetime			0.06-52.4 m	-	-	$\sigma imes \mathcal{B} =$ 1 pb, $m(s) =$ 150 GeV	1902.03094
	$W \to N\ell, N \to \ell\ell\nu$ d	isplaced vtx ($\mu\mu$, μe , ee) +	-μ 139	N lifetime		0.74-42 mm		_		m(N) = 6 GeV, Dirac	2204.11988
	$W o N\ell, N o \ell\ell u$ d	isplaced vtx ($\mu\mu$, μe , ee) +	·μ 139	N lifetime		3.1-33 mm				m(N) = 6 GeV, Majorana	2204.11988
	$W o N\ell$, $N o \ell\ell \nu$ d	isplaced vtx ($\mu\mu$, μe , ee) +	e 139	N lifetim <mark>e</mark>		0.49-81 mm				m(N) = 6 GeV, Dirac	2204.11988
	$W \to N\ell, N \to \ell\ell\nu$ d	isplaced vtx ($\mu\mu,\mu e,ee$) +	e 139	N life <mark>time</mark>		0.39-51 mm				m(N)= 6 GeV, Majorana	2204.11988
		s = 13 TeV √s = 13		0.0			0.1	1	10	¹⁰⁰ cτ [m]	
		$s = 13 \text{ TeV} \sqrt{s} = 13$									

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Summary: ATLAS SUSY Searches

ATLAS SUSY Searches* - 95% CL Lower Limits

00	ly 2024 Model	S	Signatur	′e ∫	<i>Ĺdt</i> [fb⁻	Mass limit	$\sqrt{s} = 13$ Reference
2	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q \tilde{\chi}_1^0$	0 <i>e</i> ,µ mono-jet	2-6 jets 1-3 jets	$E_T^{ m miss} \ E_T^{ m miss}$	140 140	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	2010.14293 2102.10874
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q \bar{q} \tilde{\chi}_1^0$	0 <i>e</i> , <i>µ</i>	2-6 jets	$E_T^{\rm miss}$	140	\tilde{g} 2.3 $m(\tilde{\chi}_1^0)=0 \text{ GeV}$ \tilde{g} Forbidden 1.15-1.95 $m(\tilde{\chi}_1^0)=1000 \text{ GeV}$	2010.14293 2010.14293
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\bar{q}W\tilde{\chi}_1^0$	1 <i>e</i> , <i>µ</i>	2-6 jets		140	\tilde{g} 2.2 m($\tilde{\chi}_1^0$)<600 GeV	2101.01629
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\bar{q}(\ell\ell)\tilde{\chi}^0_1$	$ee, \mu\mu$	2 jets	$E_T^{\rm miss}$	140	\tilde{g} 2.2 m($\tilde{\chi}_1^0$)<700 GeV	2204.13072
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow qqWZ\tilde{\chi}_1^0$	0 e,μ SS e,μ	7-11 jets 6 jets	E_T^{miss}	140 140	$ \begin{array}{c} \tilde{g} \\ \tilde{g} \\ \end{array} \begin{array}{c} 1.15 \\ m(\tilde{g}) - m(\tilde{\chi}_1^0) < 600 \text{ GeV} \\ m(\tilde{g}) - m(\tilde{\chi}_1^0) = 200 \text{ GeV} \\ \end{array} $	2008.06032 2307.01094
	$\tilde{g}\tilde{g}, \; \tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$	0-1 <i>e</i> ,μ SS <i>e</i> ,μ	3 <i>b</i> 6 jets	$E_T^{\rm miss}$	140 140	$\begin{array}{c} \tilde{g} \\ \tilde{g} \end{array} \qquad \begin{array}{c} \textbf{2.45} & m(\tilde{\chi}_1^0) < 500 \text{GeV} \\ m(\tilde{g}) - m(\tilde{\chi}_1^0) = 300 \text{GeV} \end{array}$	2211.08028 1909.08457
	$ ilde{b}_1 ilde{b}_1$	0 <i>e</i> , <i>µ</i>	2 <i>b</i>	$E_T^{ m miss}$	140	$ \begin{array}{c c} \tilde{b}_1 & & \\ \tilde{b}_1 & & \\ \tilde{b}_1 & & \\ \end{array} \\ \hline 10 \text{ GeV} < \Delta m (\tilde{b}_1 \tilde{\chi}_1^0) < 400 \text{ GeV} \\ & 10 \text{ GeV} < \Delta m (\tilde{b}_1 \tilde{\chi}_1^0) < 20 \text{ GeV} \\ \end{array} $	2101.12527 2101.12527
	$\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 {\rightarrow} b \tilde{\chi}_2^0 {\rightarrow} b h \tilde{\chi}_1^0$	0 <i>e</i> ,μ 2 τ	6 <i>b</i> 2 <i>b</i>	$E_T^{ m miss} \ E_T^{ m miss}$	140 140	$\begin{array}{c c} \tilde{b}_1 & \text{Forbidden} & 0.23-1.35 \\ \tilde{b}_1 & 0.13-0.85 & \Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) = 130 \text{ GeV}, \ m(\tilde{\chi}_1^0) = 100 \text{ GeV} \\ \Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) = 130 \text{ GeV}, \ m(\tilde{\chi}_1^0) = 0 \text{ GeV} \end{array}$	1908.03122 2103.08189
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$	0-1 <i>e</i> , µ	≥ 1 jet	$E_T^{\rm miss}$	140	\tilde{t}_1 1.25 m($\tilde{\chi}_1^0$)=1 GeV	2004.14060, 2012.03799
l	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow W b \tilde{\chi}_1^0$	1 <i>e</i> , <i>µ</i>	3 jets/1 <i>b</i>	$E_T^{\rm miss}$	140	\tilde{t}_1 Forbidden 1.05 m($\tilde{\chi}_1^0$)=500 GeV	2012.03799, 2401.13430
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow \tilde{\tau}_1 b \nu, \tilde{\tau}_1 \rightarrow \tau \tilde{G}$	1-2 <i>τ</i>		1	140	\tilde{t}_1 Forbidden 1.4 $m(\tilde{\tau}_1)=800 \text{ GeV}$	2108.07665
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow c\tilde{\chi}_1^0 / \tilde{c}\tilde{c}, \tilde{c} \rightarrow c\tilde{\chi}_1^0$	0 e,μ 0 e,μ	2 <i>c</i> mono-jet	$E_T^{ m miss} \ E_T^{ m miss}$	36.1 140	$ \begin{array}{c} \tilde{c} & & & & \\ \tilde{t}_1 & & & 0.55 \end{array} & & & & & \\ m(\tilde{\chi}_1^0) = 0 \text{ GeV} & & & \\ m(\tilde{t}_1, \tilde{c}) - m(\tilde{\chi}_1^0) = 5 \text{ GeV} \end{array} $	1805.01649 2102.10874
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{\chi}_2^0, \tilde{\chi}_2^0 \rightarrow Z/h\tilde{\chi}_1^0$	1-2 <i>e</i> ,μ	1-4 <i>b</i>	E_T^{miss}	140	\tilde{t}_1 0.067-1.18 m($\tilde{\chi}_2^0$)=500 GeV	2006.05880
	$\tilde{t}_{2}\tilde{t}_{2}, \tilde{t}_{2} \rightarrow \tilde{t}_{1} + Z$	3 <i>e</i> , µ	1 <i>b</i>	E_T^{miss}	140	\tilde{t}_2 Forbidden 0.86 $m(\tilde{\chi}_1^0)=360 \text{ GeV}, m(\tilde{t}_1)-m(\tilde{\chi}_1^0)=40 \text{ GeV}$	2006.05880
	$ ilde{\chi}_1^{\pm} ilde{\chi}_2^0$ via WZ	Multiple ℓ /jet $ee, \mu\mu$	ts ≥ 1 jet	$E_T^{ m miss} \ E_T^{ m miss}$	140 140	$ \begin{array}{ccc} \tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0} & & & \\ \tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0} & & & \\ \end{array} \\ \begin{array}{ccc} m(\tilde{\chi}_{1}^{0})=0, \text{ wino-bino} \\ m(\tilde{\chi}_{1}^{\pm})-m(\tilde{\chi}_{1}^{0})=5 \text{ GeV}, \text{ wino-bino} \\ \end{array} $	2106.01676, 2108.07586 1911.12606
	$ ilde{\chi}_1^{\pm} ilde{\chi}_1^{\mp}$ via WW	2 <i>e</i> , <i>µ</i>			140	$\tilde{\chi}_1^{\pm}$ 0.42 m($\tilde{\chi}_1^0$)=0, wino-bino	1908.08215
	$ ilde{\chi}_1^{\pm} ilde{\chi}_2^0$ via Wh	Multiple ℓ/jet	ts	$E_T^{ ext{miss}} \ E_T^{ ext{miss}}$	140	$\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ Forbidden 1.06 m($\tilde{\chi}_1^0$)=70 GeV, wino-bino	2004.10894, 2108.07586
	$\tilde{\chi}_{1}^{\pm}\tilde{\chi}_{1}^{\mp}$ via $\tilde{\ell}_{L}/\tilde{\nu}$	2 <i>e</i> ,µ		E_T^{miss}	140	\tilde{X}_{1}^{\pm} 1.0 $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{X}_{1}^{\pm})+m(\tilde{X}_{1}^{0}))$	1908.08215
nirect	$ \tilde{\tau}\tilde{\tau}, \tilde{\tau} \to \tau \tilde{\chi}_1^0 \tilde{\ell}_{\mathrm{L,R}} \tilde{\ell}_{\mathrm{L,R}}, \tilde{\ell} \to \ell \tilde{\chi}_1^0 $	2 τ 2 e,μ	0 jets	E_T^{miss} E^{miss}	140 140	$\tilde{\tau}$ $[\tilde{\tau}_R \tilde{\tau}_R]$ 0.35 0.5 $\tilde{\ell}$ 0.7 0.7	2402.00603 1908.08215
σ		$ee, \mu\mu$	≥ 1 jet	E_T^{miss} E_T^{miss}	140	$\tilde{\ell}$ 0.26 m($\tilde{\ell}$)-m($\tilde{\chi}_1^0$)=10 GeV	1911.12606
	$\tilde{H}\tilde{H},\tilde{H}{ ightarrow}h\tilde{G}/Z\tilde{G}$	0 e,μ 4 e,μ	$\geq 3 b$ 0 jets ≥ 2 large jet	$E_{T_{\text{miss}}}^{\text{miss}}$	140 140 140	$ \begin{array}{c} \tilde{H} \\ \tilde{H} \\ \tilde{H} \end{array} \qquad \begin{array}{c} \textbf{O.94} \\ \textbf{O.55} \end{array} \qquad \begin{array}{c} BR(\tilde{\chi}^0_1 \to h\tilde{G}) = 1 \\ BR(\tilde{\chi}^0_1 \to Z\tilde{G}) = 1 \end{array} $	2401.14922 2103.11684
		$0 e, \mu$	≥ 2 large jet	ts $E_T^{T_{miss}}$	140	\tilde{H} 0.55 $BR(\tilde{\chi}_1^d \to Z\tilde{G})=1$ \tilde{H} 0.45-0.93 $BR(\tilde{\chi}_1^0 \to Z\tilde{G})=1$	2108.07586
		2 <i>e</i> , <i>µ</i>	≥ 2 jets	$E_T^{\rm miss}$	140	$\tilde{H} \qquad \qquad \mathbf{BR}(\tilde{\chi}_1^0 \to Z\tilde{G}) = \mathbf{BR}(\tilde{\chi}_1^0 \to h\tilde{G}) = 0.5$	2204.13072
	Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	t 1 jet	$E_T^{\rm miss}$	140	$ \begin{array}{c c} \tilde{\chi}_{1}^{\pm} & 0.66 \\ \tilde{\chi}_{1}^{\pm} & 0.21 \end{array} \end{array} $	2201.02472 2201.02472
particles	Stable \tilde{g} R-hadron	pixel dE/dx		$E_T^{\rm miss}$	140	<i>ğ</i> 2.05	2205.06013
	Metastable \tilde{g} R-hadron, $\tilde{g} \rightarrow qq \tilde{\chi}_1^0$	pixel dE/dx		$E_T^{ m miss} \ E_T^{ m miss} \ E_T^{ m miss} \ E_T^{ m miss}$	140	\tilde{g} [$\tau(\tilde{g})$ =10 ns] 2.2 m($\tilde{\chi}_1^0$)=100 GeV	2205.06013
Da	$\tilde{\ell}\tilde{\ell},\tilde{\ell}{ ightarrow}\ell\tilde{G}$	Displ. lep		$E_T^{\rm miss}$	140	$\tilde{e}, \tilde{\mu}$ 0.74 $\tilde{\tau}$ 0.36	ATLAS-CONF-2024-011 ATLAS-CONF-2024-011
		pixel dE/dx	($E_T^{\rm miss}$	140	τ 0.36 $\tilde{\tau}$ 0.36 $\tau(\tilde{\ell}) = 10 \text{ ns}$	2205.06013
1	$\tilde{\chi}_1^{\pm} \tilde{\chi}_1^{\mp} / \tilde{\chi}_1^0$, $\tilde{\chi}_1^{\pm} \rightarrow Z \ell \rightarrow \ell \ell \ell$	3 <i>e</i> ,µ			140	$\tilde{\chi}_{1}^{\mp}/\tilde{\chi}_{1}^{0}$ [BR($Z\tau$)=1, BR(Ze)=1] 0.625 1.05	2011.10543
	$\tilde{\chi}_{1}^{\pm}\tilde{\chi}_{1}^{\mp}/\tilde{\chi}_{2}^{0} \to WW/Z\ell\ell\ell\ell\nu\nu$	4 <i>e</i> , <i>µ</i>	0 jets ⊳ 8 iete	$E_T^{\rm miss}$	140	$\tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0}$ [$\lambda_{i33} \neq 0, \lambda_{12k} \neq 0$] 0.95 1.55 m($\tilde{\chi}_{1}^{0}$)=200 GeV	2103.11684
	$\tilde{g}\tilde{g}, \tilde{g} \to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to qqq$ $\tilde{t}\tilde{t}, \tilde{t} \to t\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to tbs$		≥8 jets Multiple		140 36.1	\tilde{g} $[m(\tilde{\chi}_1^0)=50 \text{ GeV}, 1250 \text{ GeV}]$ 1.6 2.34 Large λ_{112}''' \tilde{t} $[\lambda_{323}''=2e-4, 1e-2]$ 0.55 1.05 m(\tilde{\chi}_1^0)=200 \text{ GeV, bino-like}	2401.16333 ATLAS-CONF-2018-003
	$tt, t \to t\chi_1, \chi_1 \to tbs$ $t\tilde{t}, \tilde{t} \to b\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^{\pm} \to bbs$		$\geq 4b$		140	t t_{323} t_{323} $t_{1.05}$ $m(\chi_1)=200$ GeV, bino-like \tilde{t} Forbidden 0.95 $m(\tilde{\chi}_1^+)=500$ GeV	2010.01015
	$\tilde{t}_1, \tilde{t}_1 \rightarrow bs$		2 jets + 2 <i>b</i>	Ь	36.7	$\tilde{t}_1 \ [qq, bs]$ 0.42 0.61	1710.07171
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow q\ell$	2 <i>e</i> , <i>µ</i>	2 <i>b</i>		140 136	\tilde{t}_1 0.4-1.85 BR $(\tilde{t}_1 \rightarrow be/b\mu) > 20\%$	2406.18367
	$\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0/\tilde{\chi}_1^0, \tilde{\chi}_{1,2}^0 \rightarrow tbs, \tilde{\chi}_1^+ \rightarrow bbs$	1μ 1-2 e μ	DV >6 iots			$\tilde{t}_{1} [1e-10 < \lambda'_{23k} < 1e-8, 3e-10 < \lambda'_{23k} < 3e-9] \qquad 1.0 \qquad 1.6 \qquad BR(\tilde{t}_{1} \to q\mu) = 100\%, \cos\theta_{t} = 1$	2003.11956
	$\lambda_1 / \lambda_2 / \lambda_1, \chi_{1,2}^{-} \rightarrow los, \chi_1 \rightarrow obs$	1-2 <i>e</i> , µ	≥6 jets		140	$\tilde{\chi}_1^0$ 0.2-0.32 Pure higgsino	2106.09609

phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

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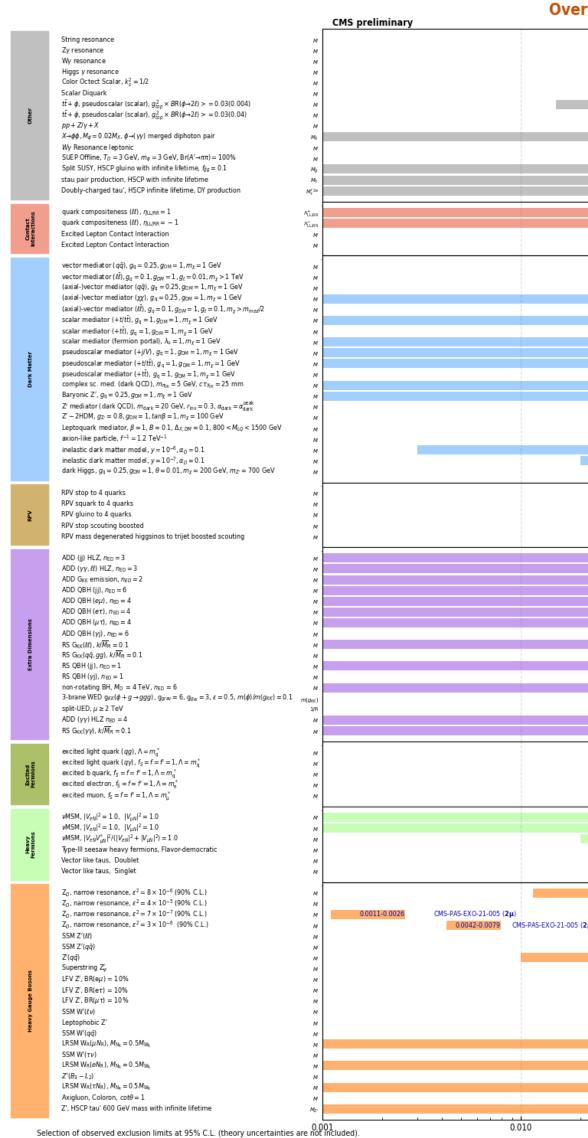


ATLAS Preliminary





Summary: CMS EXO Searches



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Overview of CMS EXO results

		0.5-7.9 1911.0	3947 (2 j)
		0.35-4.0 1712.03143 (2µ + 1γ; 2e	
		1.5-8.02106.1	0509 (1j + 1 γ)
		0.72-3.25 1808.0 1257 (1j + 1y)	
		0.5-3.7 1911.03947 (2j) 0.5-7.5 1911.039	947 (2i)
0.015-0.075 1911.0496	8 (3 <i>l</i> , ≥ 4 <i>l</i>)		
	0.108-0.34 1911.04968 (3ℓ, ≥ 4ℓ)		
		0.6-1.6 CMS-PAS-EXO-19-009 (pp + <i>ll</i> , pp + γ)	
	U.	0-1.2 CMS-PAS-EXO-22-022 (2(γγ)) 0.3-2.0 CMS-PAS-EXO-21-017 ((ℓ + p ^{miss} + γ))	
		0.2-2.0 CMS-PAS-EXO-23-002 ((SUEPOffline))	
		0.0-2.13 CMS-PAS-EXO-18-002 (dE/dx)	
	0.0-0.69 CMS-PAS-	EXO-18-002 (dE/dx)	
		0.0-1.46 CMS-PAS-EXO-18-002 (dE/dx)	
			0.0-24.0 2103.02708 (2/)
			0.0-36.0 2103.0 2708 (2
		0.2-5.6 2001.04521 (2e 0.2-5.7 2001.04521 (2µ	
		0.2-5.7 2001.04521 (Zj	+2]/
	0.35-0.7 1911.037	61 (≥ 3 j)	
		0.2-1.92 2103.02708 (2e, 2µ)	
		0.5-2.8 1911.03947 (2j) 0.0-1.95 2107.13021 (≥ 1j + p ^{-rtss})	
		0.2-4.64 2103.02708 (2e , 2 µ)	
	$0.0-0.29$ 1901.01553 (0, 1 <i>l</i> + \ge 2 <i>j</i> + p_T^{miss})		
	0.05-0.4 2107.10892 (0, 1 ℓ + ≥ 2j		
	0.0-0.47 2107.1 3021 (≥ 1j +	$0.0-1.5$ 2107.1 3021 (\geq 1j + p _T ^{riss}) p_T^{riss}	
	$0.0-0.3$ 1901.01553 (0, $1/t + \ge 2j + p_T^{m(ss)}$)		
	0.05-0.42 2107.10892 (0, 1 ℓ + ≥	2j + p _T ^{m(ss})	
		0.0-1.54 1810.10069 (4j)	
		0.0-1.6 1908.0 1713 (h + p _T ^{mbs}) 15.5 12112 11125 (2i + p	m ⁽²⁵⁾
		1.5-5.1 2112.11125 (2j + p 0.5-3.1 1908.01713 (h + p _m ^{thss})	T '
	0.3-0.6 1811.10151 (
		0.5-2.0 CMS-PAS-EXO-21-007 (pp + γγ)	
	-EXO-20-010 (2 displaced μ + p ^{mbs}) -EXO-20-010 (2 displaced μ + p ^{mbs})		
0.02-0.08 CMS-PAS-	0.16-0.352 CMS-PAS-EXO-21-012 (1ℓ + 2	$2j + p_T^{miss}, 2\ell + p_T^{miss})$	
	0.08-0.52 1808.03124 (2j; 4		
	0.1-0.72 1806.010	058 (2j) 0.1-1.41 1806.01058 (2j)	
	0.07-0.2 CMS-PAS-EXO-21-004 (scouting boosted dije		
0.07-0.075 & 0 <mark>.0</mark> 95-0.105 C	MS-PAS-EXO-21-004 (scouting boosted trijet)		
			12.0 1803.08030 (2j)
			.2.10443 (2γ,2ℓ) 8 2107.13021 (≥ 1j + p ^{miss})
		0.0-8.2 1803.0	
		0.0-5.6 2205.06709 (eµ)	
		0.0-5.2 2205.06709 (et)	
		0.0-5.0 2205.06709 (μτ)	-EXO-20-012 (y + j)
		0.0-4.78 2103.0 2708 (2/)	-240-20-012 (¥+)/
		0.5-2.6 1911.0 3947 (2j)	
		0.0-5.9 1803.08030 (2 j	
		2.0-5.2 CMS-PAS-EXO-20-0 0.0-9 7 1	$12 (\gamma + j)$ $805.06013 (\geq 7j(\ell, \gamma))$
		2.0-4.3 2201.02140 (2)	
		0.4-2.8 2202.06075 (<i>l</i> + p _T ^{miss})	
			5-PAS-EXO-22-024 (YY)
		0.0-4.8 CMS-PAS-EX 0-22-024	(YY)
			2j)
		0.5-6.3 1911.03947 (
		1.0-6.0 CMS-PAS-EX 0-2	20-012 (y + j)
		1.0-6.0 CMS-PAS-EXO- 1.0-2 2 CMS-PAS-EXO-20-012 (γ + j)	20-012 (y + j)
		1.0-6.0 CMS-PAS-EXO- 1.0-2.2 CMS-PAS-EXO-20-012 (γ + j) 0.25-3.9 1811.03052 (γ + 2e)	20-012 (y + j)
		1.0-6.0 CMS-PAS-EXO- 1.0-2 2 CMS-PAS-EXO-20-012 (γ + j)	20-012 (γ + j)
	0.00	1.0-6.0 CMS-PAS-EXO- 1.0-2.2 CMS-PAS-EXO-20-012 (γ + j) 0.25-3.9 1811.03052 (γ + 2e)	20-012 (γ + j)
		1.0-6.0 CMS-PAS-EXO- 1.0-2 2 CMS-PAS-EXO-20-012 (γ + j) 0.25-3.9 1811.03052 (γ + 2e) 0.25-3.8 1811.03052 (γ + 2μ) 1-1.24 1802.02965; 1806.10905 (3μ; ≥ 1j + 2μ) 0.001-1.43 1802.02965; 1806.10905 (3e; ≥ 1j + 2e)	20-012 (γ + j)
	(1.0-6.0 CMS-PAS-EXO- 1.0-2.2 CMS-PAS-EXO-20-012 (γ + j) 0.25-3.9 1811.03052 (γ + 2e) 0.25-3.8 1811.03052 (γ + 2μ) 1-124 1802 02965; 1806 10905 (3μ; ≥ 1j + 2μ) 0.001-1.43 1802 02965; 1806 1.0905 (3e; ≥ 1j + 2e) 0.02-1.6 1806.10905 (≥ 1j + μ + e)	
	0.1-0.98	1.0-6.0 CMS-PAS-EXO- 1.0-2.2 CMS-PAS-EXO-20-012 (γ + j) 0.25-3.9 1811.03052 (γ + 2e) 0.25-3.8 1811.03052 (γ + 2μ) 1-1.24 1802.02965; 1806.10905 (3μ; ≥ 1j + 2μ) 0.001-1.43 1802.02965; 1806.10905 (3ε; ≥ 1j + 2e) 0.02-1.6 1806.10905 (≥ 1j + μ + e) 2202.08676 (3ℓ, ≥ 4ℓ, 1π + 3ℓ, 2π + 2ℓ, 3π + 1ℓ, 1π + 2ℓ, 2π + 1ℓ)	,
01	0.1-0.98	$\begin{array}{c} 1.0-6.0 \ \text{CMS-PAS-EXO-} \\ \hline 1.0-2.2 \ \text{CMS-PAS-EXO-} \\ \hline 1.0-2.2 \ \text{CMS-PAS-EXO-} \\ \hline 0.25-3.9 \ 1811.03052 \ (\mathbf{y}+2\mathbf{e}) \\ \hline 0.25-3.8 \ 1811.03052 \ (\mathbf{y}+2\mathbf{e}) \\ \hline 1.1 \ 24 \ 1802.02965; \ 1806.10905 \ (3\mathbf{\mu}; \geq 1\mathbf{j}+2\mathbf{\mu}) \\ \hline 0.001-1.43 \ 1802.02965; \ 1806.10905 \ (3\mathbf{e}; \geq 1\mathbf{j}+2\mathbf{e}) \\ \hline 0.02-1.6 \ 1806.10905 \ (\geq 1\mathbf{j}+\mathbf{\mu}+\mathbf{e}) \\ \hline 2020.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 5 \ 2202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.24 \ 1802.0295 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+2t, \ 3\mathbf{r}+1t, \$,
	0.1-0.98 0.1-1.04 125- <mark>0.15</mark> 2202.08676 (3ℓ, ≥ 4ℓ, 1τ + 3ℓ, 2τ + 2ℓ, 3τ + 1ℓ, 1τ -	$\begin{array}{c} 1.0-6.0 \ \text{CMS-PAS-EXO-} \\ \hline 1.0-2.2 \ \text{CMS-PAS-EXO-} \\ \hline 1.0-2.2 \ \text{CMS-PAS-EXO-} \\ \hline 0.25-3.9 \ 1811.03052 \ (\mathbf{y}+2\mathbf{e}) \\ \hline 0.25-3.8 \ 1811.03052 \ (\mathbf{y}+2\mathbf{e}) \\ \hline 1.1 \ 24 \ 1802.02965; \ 1806.10905 \ (3\mathbf{\mu}; \geq 1\mathbf{j}+2\mathbf{\mu}) \\ \hline 0.001-1.43 \ 1802.02965; \ 1806.10905 \ (3\mathbf{e}; \geq 1\mathbf{j}+2\mathbf{e}) \\ \hline 0.02-1.6 \ 1806.10905 \ (\geq 1\mathbf{j}+\mathbf{\mu}+\mathbf{e}) \\ \hline 2020.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 5 \ 2202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.24 \ 1802.0295 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+2t, \ 3\mathbf{r}+1t, \$,
0.1 0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 225 <mark>-0.15</mark> 2202.08676 (3/, ≥ 4/, 1τ + 3/, 2τ + 2/, 3τ + 1/, 1τ - ′6 (2 μ)	$\begin{array}{c} 1.0-6.0 \ \text{CMS-PAS-EXO-} \\ \hline 1.0-2.2 \ \text{CMS-PAS-EXO-} \\ \hline 1.0-2.2 \ \text{CMS-PAS-EXO-} \\ \hline 0.25-3.9 \ 1811.03052 \ (\mathbf{y}+2\mathbf{e}) \\ \hline 0.25-3.8 \ 1811.03052 \ (\mathbf{y}+2\mathbf{e}) \\ \hline 1.1 \ 24 \ 1802.02965; \ 1806.10905 \ (3\mathbf{\mu}; \geq 1\mathbf{j}+2\mathbf{\mu}) \\ \hline 0.001-1.43 \ 1802.02965; \ 1806.10905 \ (3\mathbf{e}; \geq 1\mathbf{j}+2\mathbf{e}) \\ \hline 0.02-1.6 \ 1806.10905 \ (\geq 1\mathbf{j}+\mathbf{\mu}+\mathbf{e}) \\ \hline 2020.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 5 \ 2202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.24 \ 1802.0295 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+2t, \ 3\mathbf{r}+1t, \$,
	0.1-0.98 0.1-1.04 125- <mark>0.15</mark> 2202.08676 (3ℓ, ≥ 4ℓ, 1τ + 3ℓ, 2τ + 2ℓ, 3τ + 1ℓ, 1τ -	$\begin{array}{c} 1.0-6.0 \ \text{CMS-PAS-EXO-} \\ \hline 1.0-2.2 \ \text{CMS-PAS-EXO-} \\ \hline 1.0-2.2 \ \text{CMS-PAS-EXO-} \\ \hline 0.25-3.9 \ 1811.03052 \ (\mathbf{y}+2\mathbf{e}) \\ \hline 0.25-3.8 \ 1811.03052 \ (\mathbf{y}+2\mathbf{e}) \\ \hline 1.1 \ 24 \ 1802.02965; \ 1806.10905 \ (3\mathbf{\mu}; \geq 1\mathbf{j}+2\mathbf{\mu}) \\ \hline 0.001-1.43 \ 1802.02965; \ 1806.10905 \ (3\mathbf{e}; \geq 1\mathbf{j}+2\mathbf{e}) \\ \hline 0.02-1.6 \ 1806.10905 \ (\geq 1\mathbf{j}+\mathbf{\mu}+\mathbf{e}) \\ \hline 2020.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 5 \ 2202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.24 \ 1802.0295 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+2t, \ 3\mathbf{r}+1t, \$,
	(0.1-0.98 0.1-1.04 225 <mark>-0.15</mark> 2202.08676 (3/, ≥ 4/, 1τ + 3/, 2τ + 2/, 3τ + 1/, 1τ - ′6 (2 μ)	$\begin{array}{c} 1.0-6.0 \ \text{CMS-PAS-EXO-} \\ \hline 1.0-2.2 \ \text{CMS-PAS-EXO-} \\ \hline 1.0-2.2 \ \text{CMS-PAS-EXO-} \\ \hline 0.25-3.9 \ 1811.03052 \ (\mathbf{y}+2\mathbf{e}) \\ \hline 0.25-3.8 \ 1811.03052 \ (\mathbf{y}+2\mathbf{e}) \\ \hline 1.1 \ 24 \ 1802.02965; \ 1806.10905 \ (3\mathbf{\mu}; \geq 1\mathbf{j}+2\mathbf{\mu}) \\ \hline 0.001-1.43 \ 1802.02965; \ 1806.10905 \ (3\mathbf{e}; \geq 1\mathbf{j}+2\mathbf{e}) \\ \hline 0.02-1.6 \ 1806.10905 \ (\geq 1\mathbf{j}+\mathbf{\mu}+\mathbf{e}) \\ \hline 2020.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 5 \ 2202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.24 \ 1802.0295 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+2t, \ 3\mathbf{r}+1t, \$,
	(0.1-0.98 0.1-1.04 225 <mark>-0.15</mark> 2202.08676 (3/, ≥ 4/, 1τ + 3/, 2τ + 2/, 3τ + 1/, 1τ - ′6 (2 μ)	$\begin{array}{c} 1.0-6.0 \ \text{CMS-PAS-EXO-} \\ \hline 1.0-2.2 \ \text{CMS-PAS-EXO-} \\ \hline 1.0-2.2 \ \text{CMS-PAS-EXO-} \\ \hline 0.25-3.9 \ 1811.03052 \ (\mathbf{y}+2\mathbf{e}) \\ \hline 0.25-3.8 \ 1811.03052 \ (\mathbf{y}+2\mathbf{e}) \\ \hline 1.1 \ 24 \ 1802.02965; \ 1806.10905 \ (3\mathbf{\mu}; \geq 1\mathbf{j}+2\mathbf{\mu}) \\ \hline 0.001-1.43 \ 1802.02965; \ 1806.10905 \ (3\mathbf{e}; \geq 1\mathbf{j}+2\mathbf{e}) \\ \hline 0.02-1.6 \ 1806.10905 \ (\geq 1\mathbf{j}+\mathbf{\mu}+\mathbf{e}) \\ \hline 2020.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 5 \ 2202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.24 \ 1802.0295 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 2\mathbf{r}+1t \\ \hline 1.25 \ 1202.08676 \ (3t, \geq 4t, \ 1\mathbf{r}+3t, \ 2\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 1\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+2t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+1t, \ 3\mathbf{r}+2t, \ 3\mathbf{r}+1t, \$) () ()
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 225 <u>-0.15</u> 2202.08676 (3 <i>t</i> , ≥ 4 <i>t</i> , 1τ + 3 <i>t</i> , 2τ + 2 <i>t</i> , 3τ + 1 <i>t</i> , 1τ · ⁽⁶ (2μ) 0.11-0.2 1912.04776 (2μ)	$\begin{array}{c} 1.0-6.0\ \text{CMS-PAS-EXO-}\\ \hline 1.0-2.2\ \text{CMS-PAS-EXO-}\\ \hline 1.0-2.2\ \text{CMS-PAS-EXO-}\\ \hline 0.25-3.9\ 1811.03052\ (\textbf{y}+2\textbf{e})\\ \hline 0.25-3.8\ 1811.03052\ (\textbf{y}+2\textbf{\mu})\\ \hline 1.1.24\ 1802.02965;\ 1806\ 1.0905\ (\textbf{3}\textbf{\mu}; \geq \textbf{1}\textbf{j}+2\textbf{\mu})\\ \hline 0.001-1.43\ 1802.02965;\ 1806\ 1.0905\ (\textbf{3}\textbf{e}; \geq \textbf{1}\textbf{j}+2\textbf{e})\\ \hline 0.02-1.6\ 1806.10905\ (\geq \textbf{1}\textbf{j}+\textbf{\mu}+\textbf{e})\\ 2202.08676\ (\textbf{3}t, \geq 4t,\ \textbf{1}\tau+3t,\ \textbf{2}\tau+2t,\ \textbf{3}\tau+1t,\ \textbf{1}\tau+2t,\ \textbf{2}\tau+1t)\\ \hline 5202.08676\ (\textbf{3}t, \geq 4t,\ \textbf{1}\tau+3t,\ \textbf{2}\tau+2t,\ \textbf{3}\tau+1t,\ \textbf{1}\tau+2t,\ \textbf{2}\tau+1t)\\ +2t,\ \textbf{2}\tau+1t)\end{array}$) () ()
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 225 <mark>-0.15</mark> 2202.08676 (3/, ≥ 4/, 1τ + 3/, 2τ + 2/, 3τ + 1/, 1τ - ′6 (2 μ)	1.0-6.0 CMS-PAS-EXO- 1.0-2.2 CMS-PAS-EXO- 1.0-2.2 CMS-PAS-EXO- 1.0-2.2 CMS-PAS-EXO- 1.0-2.2 CMS-PAS-EXO- 1.0-2.5 CMS-PAS-EXO- 1.2-2.5 CMS-PAS- 1.2-2.5 CMS-PAS- 1.2-2.5 CMS-PAS- 1.2-2.5 CMS-PAS- 1.2-2.5) () ()
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 225 <u>-0.15</u> 2202.08676 (3 <i>t</i> , ≥ 4 <i>t</i> , 1τ + 3 <i>t</i> , 2τ + 2 <i>t</i> , 3τ + 1 <i>t</i> , 1τ · ⁽⁶ (2μ) 0.11-0.2 1912.04776 (2μ)	$1.0-6.0 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ CMS-PAS-EXO-} 0.25-3.9 \text{ 1811.03052 } (\mathbf{y} + 2\mathbf{e}) \\ 0.25-3.9 \text{ 1811.03052 } (\mathbf{y} + 2\mathbf{\mu}) \\ 1.1.24 \text{ 1802.02965; 1806.10905 } (3\mathbf{\mu}; \ge 1\mathbf{j} + 2\mathbf{\mu}) \\ 0.001.1.43 \text{ 1802.02965; 1806.10905 } (3\mathbf{e}; \ge 1\mathbf{j} + 2\mathbf{e}) \\ 0.02-1.6 \text{ 1806.10905 } (2\mathbf{i}; + \mathbf{\mu} + \mathbf{e}) \\ 2020.08676 (3t_{i} \ge 4t_{i}, 1\mathbf{r} + 3t_{i}, 2\mathbf{r} + 2t_{i}, 3\mathbf{r} + 1t_{i}, 1\mathbf{r} + 2t_{i}, 2\mathbf{r} + 1t_{i}) \\ 5 2202.08676 (3t_{i} \ge 4t_{i}, 1\mathbf{r} + 3t_{i}, 2\mathbf{r} + 2t_{i}, 3\mathbf{r} + 1t_{i}, 1\mathbf{r} + 2t_{i}, 2\mathbf{r} + 1t_{i}) \\ 1 = 2t_{i}, 2\mathbf{r} + 1t_{i}) \\ 0.2-5.15 \text{ 2103.02708 } (2\mathbf{e}, 2\mathbf{\mu}) \\ 0.2-4.6 \text{ 210.02708 } (2\mathbf{e}, 2\mathbf{\mu}) \\ 0.2-4.6 210.027$) () ()
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 225 <u>-0.15</u> 2202.08676 (3 <i>t</i> , ≥ 4 <i>t</i> , 1τ + 3 <i>t</i> , 2τ + 2 <i>t</i> , 3τ + 1 <i>t</i> , 1τ · ⁽⁶ (2μ) 0.11-0.2 1912.04776 (2μ)	$1.0-6.0 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 0.25-3.9 1811.03052 (y + 2e) 0.25-3.9 1811.03052 (y + 2e) 0.25-3.8 1811.03052 (y + 2\mu) 1-1.24 1802.02965; 1806 1.0905 (3µ; \ge 1j + 2\mu)0.001-1.43 1802.02965; 1806 1.0905 (3e; \ge 1j + 2e)0.02-1.6 1806.10905 (\ge 1j + \mu + e)202.08676 (3t, \ge 4t, 1t + 3t, 2t + 2t, 3t + 1t$, 1 t + 2 <i>t</i> , 2 t + 1 <i>t</i>) 5202.08676 (3 <i>t</i> , $\ge 4t$, 1 t + 3 <i>t</i> , 2 t + 2 <i>t</i> , 3 t + 1 <i>t</i> , 1 t + 2 <i>t</i> , 2 t + 1 <i>t</i>) + 2 <i>t</i> , 2 t + 1 <i>t</i>) 0.2-5.15 2103.02708 (2e, 2µ) 0.2-6 2103.02708 (2e, 2µ) 0.2-6 2205.06709 (eµ)) () ()
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 225 <u>-0.15</u> 2202.08676 (3 <i>t</i> , ≥ 4 <i>t</i> , 1τ + 3 <i>t</i> , 2τ + 2 <i>t</i> , 3τ + 1 <i>t</i> , 1τ · ⁽⁶ (2μ) 0.11-0.2 1912.04776 (2μ)	$1.0-6.0 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ CMS-PAS-EXO-} 0.25-3.9 \text{ 1811.03052 } (\mathbf{y} + 2\mathbf{e}) \\ 0.25-3.9 \text{ 1811.03052 } (\mathbf{y} + 2\mathbf{\mu}) \\ 1.1.24 \text{ 1802.02965; 1806.10905 } (3\mathbf{\mu}; \ge 1\mathbf{j} + 2\mathbf{\mu}) \\ 0.001.1.43 \text{ 1802.02965; 1806.10905 } (3\mathbf{e}; \ge 1\mathbf{j} + 2\mathbf{e}) \\ 0.02-1.6 \text{ 1806.10905 } (2\mathbf{i}; + \mathbf{\mu} + \mathbf{e}) \\ 2020.08676 (3t_{i} \ge 4t_{i}, 1\mathbf{r} + 3t_{i}, 2\mathbf{r} + 2t_{i}, 3\mathbf{r} + 1t_{i}, 1\mathbf{r} + 2t_{i}, 2\mathbf{r} + 1t_{i}) \\ 5 2202.08676 (3t_{i} \ge 4t_{i}, 1\mathbf{r} + 3t_{i}, 2\mathbf{r} + 2t_{i}, 3\mathbf{r} + 1t_{i}, 1\mathbf{r} + 2t_{i}, 2\mathbf{r} + 1t_{i}) \\ 1 = 2t_{i}, 2\mathbf{r} + 1t_{i}) \\ 0.2-5.15 \text{ 2103.02708 } (2\mathbf{e}, 2\mathbf{\mu}) \\ 0.2-4.6 \text{ 210.02708 } (2\mathbf{e}, 2\mathbf{\mu}) \\ 0.2-4.6 210.027$) () ()
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 225 <u>-0.15</u> 2202.08676 (3 <i>t</i> , ≥ 4 <i>t</i> , 1τ + 3 <i>t</i> , 2τ + 2 <i>t</i> , 3τ + 1 <i>t</i> , 1τ · ⁽⁶ (2μ) 0.11-0.2 1912.04776 (2μ)	$1.0-6.0 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ CMS-PAS-EXO-} 0.25-3.0 \text{ IB11.03052 } (\mathbf{y} + 2\mathbf{e}) \\ 0.25-3.0 \text{ IB11.03052 } (\mathbf{y} + 2\mathbf{e}) \\ 0.25-3.8 \text{ IB11.03052 } (\mathbf{y} + 2\mathbf{\mu}) \\ 1-1.24 \text{ IB02.02965; IB06.10905 } (3\mathbf{\mu}; \ge 1\mathbf{j} + 2\mathbf{\mu}) \\ 0.001-1.43 \text{ IB02.02965; IB06.10905 } (3\mathbf{e}; \ge 1\mathbf{j} + 2\mathbf{e}) \\ 0.02-1.6 \text{ IB06.10905 } (3\mathbf{e}; \ge 1\mathbf{j} + 2\mathbf{e}) \\ 0.02-1.6 \text{ IB06.10905 } (3\mathbf{e}; \ge 1\mathbf{j} + \mathbf{\mu} + \mathbf{e}) \\ 2202.08676 \ (3t, \ge 4t, 1\mathbf{r} + 3t, 2\mathbf{r} + 2t, 3\mathbf{r} + 1t, 1\mathbf{r} + 2t, 2\mathbf{r} + 1t) \\ 5202.08676 \ (3t, \ge 4t, 1\mathbf{r} + 3t, 2\mathbf{r} + 2t, 3\mathbf{r} + 1t, 1\mathbf{r} + 2t, 2\mathbf{r} + 1t) \\ + 2t, 2\mathbf{r} + 1t) \\ 0.2-5.15 \ 2103.02708 \ (2\mathbf{e}, 2\mathbf{\mu}) \\ 0.2-6 \ 2103.02708 \ (2\mathbf{e}, 2\mathbf{\mu}) \\ 0.2-5.0 \ 2205.06709 \ (\mathbf{e}\mathbf{\mu}) \\ 0.2-4.3 \ 2205.06709 \ (\mathbf{e}\mathbf{r}) \\ \end{array}$) () () () () () () () () () (
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 225 <u>-0.15</u> 2202.08676 (3 <i>t</i> , ≥ 4 <i>t</i> , 1τ + 3 <i>t</i> , 2τ + 2 <i>t</i> , 3τ + 1 <i>t</i> , 1τ · ⁽⁶ (2μ) 0.11-0.2 1912.04776 (2μ)	$1.0-6.0 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 0.12 \text{ (y + j)} 0.25-3.9 \text{ 1811.03052 (y + 2e)} 0.25-3.8 \text{ 1811.03052 (y + 2e)} 0.25-3.8 \text{ 1811.03052 (y + 2\mu)} 1.1.24 \text{ 1802.02965; 1806.10905 (3\mu; \geq 1j + 2\mu)} 0.001-1.43 1802.02965; 1806.10905 (3e; \geq 1j + 2e) 0.02-1.6 1806.10905 (\geq 1j + \mu + e) 2202.08676 (3t \geq 4t, 1\tau + 3t, 2\tau + 2t, 3\tau + 1t, 1\tau + 2t, 2\tau + 1t) 15 2202.08676 (3t \geq 4t, 1\tau + 3t, 2\tau + 2t, 3\tau + 1t, 1\tau + 2t, 2\tau + 1t) 15 2202.08676 (3t \geq 4t, 1\tau + 3t, 2\tau + 2t, 3\tau + 1t, 1\tau + 2t, 2\tau + 1t) 0.2-5.15 2103.02708 (2e, 2µ) 0.2-5.0 2205.06709 (eµ) 0.2-4.5 2205.06709 (eµ) 0.2-4.3 2205.06709 (er) 0.2-4.3 2205.06709 (µr) 0.2-4.3 2202.06075 (t + 0.4-5.7 2202.0675 (t + 0.4-5.7 2202.0675 (t + 0.4-5.7 202.0675 (t + 0.4-5.7 2202.0675 (t + 0.4-5.7 202.0675 (t + 0$) () () () () () () () () () (
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 125 <u>-0.15</u> 2202.08676 (3 <i>t</i> , ≥ 4 <i>t</i> , 1 τ + 3 <i>t</i> , 2 τ + 2 <i>t</i> , 3 τ + 1 <i>t</i> , 1 τ · (6 (2μ) 0.11-0.2 1912.04776 (2μ) 125 1905.10331 (1j, 1γ)	$1.0-6.0 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 0.25-3.9 1811.03052 (y + 2e) 0.25-3.9 1811.03052 (y + 2e) 0.25-3.8 1811.03052 (y + 2µ) 1-1.24 1802.02965; 1806 1.0905 (3µ; \ge 1j + 2µ)0.001-1.43 1802.02965; 1806 1.0905 (3e; \ge 1j + 2e)0.02-1.6 1806.10905 (2 1 j + µ + e)202.08676 (3l, \ge 4l, 1r + 3l, 2r + 2l, 3r + 1l, 1r + 2l, 2r + 1l)5202.08676 (3l, \ge 4l, 1r + 3l, 2r + 2l, 3r + 1l, 1r + 2l, 2r + 1l)5202.08676 (3l, \ge 4l, 1r + 3l, 2r + 2l, 3r + 1l, 1r + 2l, 2r + 1l)+ 2l, 2r + 1l)0.2-5 15 2103.02708 (2e, 2µ)0.2-5 0 2205.06709 (er)0.2-4 3 2205.06709 (er)0.2-4 3 2205.06709 (er)0.2-4 3 2205.06709 (µr)0.2-5 17 2202.06075 (l + 0.5-3.6 1911.03947 (2j)0.5-3.6 1911.03947 (2j)$	μ ^(t)
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 125 <u>-0.15</u> 2202.08676 (3 <i>t</i> , ≥ 4 <i>t</i> , 1 τ + 3 <i>t</i> , 2 τ + 2 <i>t</i> , 3 τ + 1 <i>t</i> , 1 τ · (6 (2μ) 0.11-0.2 1912.04776 (2μ) 125 1905.10331 (1j, 1γ)	$1.0-6.0 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ CMS-PAS-EXO-} 1.0-2.5 \text{ J} 1811.03052 (\mathbf{y} + 2\mathbf{e})0.25-3.9 1811.03052 (\mathbf{y} + 2\mathbf{e})0.25-3.8 1811.03052 (\mathbf{y} + 2\mathbf{\mu})1.1.24 1802.02965; 1806.10905 (3\mathbf{\mu}; \geq 1\mathbf{j} + 2\mathbf{\mu})0.001-1.43 1802.02965; 1806.10905 (3\mathbf{\mu}; \geq 1\mathbf{j} + 2\mathbf{\mu})0.02-1.6 1806.10905 (2 \mathbf{j} + \mathbf{\mu} + \mathbf{e})202.08676 (3\mathbf{J}, \geq 4\mathbf{J}, 1\mathbf{T} + 3\mathbf{J}, 2\mathbf{T} + 2\mathbf{J}, 3\mathbf{T} + 1\mathbf{J}, 1\mathbf{T} + 2\mathbf{J}, 2\mathbf{T} + 1\mathbf{J})5 2202.08676 (3\mathbf{J}, \geq 4\mathbf{J}, 1\mathbf{T} + 3\mathbf{J}, 2\mathbf{T} + 2\mathbf{J}, 3\mathbf{T} + 1\mathbf{J}, 1\mathbf{T} + 2\mathbf{J}, 2\mathbf{T} + 1\mathbf{J}5 202.08676 (3\mathbf{J}, \geq 4\mathbf{J}, 1\mathbf{T} + 3\mathbf{J}, 2\mathbf{T} + 2\mathbf{J}, 3\mathbf{T} + 1\mathbf{J}, 1\mathbf{T} + 2\mathbf{J}, 2\mathbf{T} + 1\mathbf{J}0 2-5.0 2205.06709 (\mathbf{e})0 2-4.6 2103.0.2708 (2\mathbf{e}, 2\mathbf{\mu})0 2-4.3 2205.06709 (\mathbf{e})0 2-4.1 2205.06709 (\mathbf{e})0 2-4.5 7 2202.06075 (\mathbf{J} + \mathbf{I})0 4-5.7 202.06075 (\mathbf{J} + \mathbf{I})0 4-5.7 212.0.3949 (2\mathbf{\mu} + \mathbf{I})$) () () () () () () () ()
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 125 <u>-0.15</u> 2202.08676 (3 <i>t</i> , ≥ 4 <i>t</i> , 1 τ + 3 <i>t</i> , 2 τ + 2 <i>t</i> , 3 τ + 1 <i>t</i> , 1 τ · (6 (2μ) 0.11-0.2 1912.04776 (2μ) 125 1905.10331 (1j, 1γ)	$1.0-6.0 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 0.25-3.9 1811.03052 (y + 2e) 0.25-3.9 1811.03052 (y + 2e) 0.25-3.8 1811.03052 (y + 2µ) 1-1.24 1802.02965; 1806 1.0905 (3µ; \ge 1j + 2µ)0.001-1.43 1802.02965; 1806 1.0905 (3e; \ge 1j + 2e)0.02-1.6 1806.10905 (2 1 j + µ + e)202.08676 (3l, \ge 4l, 1r + 3l, 2r + 2l, 3r + 1l, 1r + 2l, 2r + 1l)5202.08676 (3l, \ge 4l, 1r + 3l, 2r + 2l, 3r + 1l, 1r + 2l, 2r + 1l)5202.08676 (3l, \ge 4l, 1r + 3l, 2r + 2l, 3r + 1l, 1r + 2l, 2r + 1l)+ 2l, 2r + 1l)0.2-5 15 2103.02708 (2e, 2µ)0.2-5 0 2205.06709 (er)0.2-4 3 2205.06709 (er)0.2-4 3 2205.06709 (er)0.2-4 3 2205.06709 (µr)0.2-5 17 2202.06075 (l + 0.5-3.6 1911.03947 (2j)0.5-3.6 1911.03947 (2j)$	(L) (L) (L) (L) (L) (L) (L) (L)
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 125 <u>-0.15</u> 2202.08676 (3 <i>t</i> , ≥ 4 <i>t</i> , 1 τ + 3 <i>t</i> , 2 τ + 2 <i>t</i> , 3 τ + 1 <i>t</i> , 1 τ · (6 (2μ) 0.11-0.2 1912.04776 (2μ) 125 1905.10331 (1j, 1γ)	$1.0-6.0 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 0.12 (y + j) 0.25-3.9 1811.03052 (y + 2e) 0.25-3.8 1811.03052 (y + 2\mu) 1-1.24 1802.02965; 1806 1.0905 (3µ; \ge 1j + 2µ)0.001.1.43 1802.02965; 1806 1.0905 (3e; \ge 1j + 2e)0.02-1.6 1806.10905 (\ge 1j + µ + e)2020.08676 (3k) \ge 4k, 1\tr + 3k, 2\tr + 2k, 3\tr + 1k, 1\tr + 2k, 2\tr + 1k)5 2202.08676 (3k) \ge 4k, 1\tr + 3k, 2\tr + 2k, 3\tr + 1k, 1\tr + 2k, 2\tr + 1k)5 2202.08676 (3k) \ge 4k, 1\tr + 3k, 2\tr + 2k, 3\tr + 1k, 1\tr + 2k, 2\tr + 1k + 2k, 2\tr + 1k)0.2-5.15 2103.02708 (2e, 2µ)0.2-5.0 2205.06709 (eµ)0.2-4.1 2205.06709 (er)0.2-4.1 2205.06709 (er)0.4-5.7 202.06075 (k + 0.5-3.6 1911.03947 (2j)0.6-5.0 5110.03949 (2µ + 2)0.6-4.8 2212.12604 (\tr + \tr \tr \tr 2k, 2\tr + 2k)(0.6-4.7 2112.03949 (2e + 2j)µ + \ge 1b)$	(L) (L) (L) (L) (L) (L) (L) (L)
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 0.1-1.04 125-0.15 2202.08676 (3 <i>I</i> , ≥ 4 <i>I</i> , 1τ + 3 <i>I</i> , 2τ + 2 <i>I</i> , 3τ + 1 <i>I</i> , 1τ 76 (2μ) 0.11-0.2 1912.04776 (2μ) 125 1905.10331 (1 <i>j</i> , 1γ) 0.05-0.45 1909.04114 (2 <i>j</i>)	$1.0-6.0 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 0.12 (y + j) 0.25-3.9 1811.03052 (y + 2e) 0.25-3.9 1811.03052 (y + 2\mu) 0.25-3.9 1811.03052 (y + 2\mu) 0.001-1.43 1802.02965; 1806 1.0905 (3e; \geq 1j + 2\mu) 0.001-1.43 1802.02965; 1806 1.0905 (3e; \geq 1j + 2\mu) 0.002-1.6 1806.10905 (2 1 j + \mu + e) 2202.08676 (3t, \geq 4t, 1\tau + 3t, 2\tau + 2t, 3\tau + 1t, 1\tau + 2t, 2\tau + 2t, 1\tau + 2t, 1\tau$	μ ⁽⁾ , () μ) j) ε)
0.0115-0.075 1912.0477	(0.1-0.98 0.1-1.04 0.1-1.04 125-0.15 2202.08676 (3 <i>I</i> , ≥ 4 <i>I</i> , 1τ + 3 <i>I</i> , 2τ + 2 <i>I</i> , 3τ + 1 <i>I</i> , 1τ 76 (2μ) 0.11-0.2 1912.04776 (2μ) 125 1905.10331 (1 <i>j</i> , 1γ) 0.05-0.45 1909.04114 (2 <i>j</i>)	$1.0-6.0 \text{ CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 1.0-2.2 \text{ (CMS-PAS-EXO-} 0.12 (y + j) 0.25-3.9 1811.03052 (y + 2e) 0.25-3.8 1811.03052 (y + 2\mu) 1-1.24 1802.02965; 1806 1.0905 (3µ; \ge 1j + 2µ)0.001.1.43 1802.02965; 1806 1.0905 (3e; \ge 1j + 2e)0.02-1.6 1806.10905 (\ge 1j + µ + e)2020.08676 (3k) \ge 4k, 1\tr + 3k, 2\tr + 2k, 3\tr + 1k, 1\tr + 2k, 2\tr + 1k)5 2202.08676 (3k) \ge 4k, 1\tr + 3k, 2\tr + 2k, 3\tr + 1k, 1\tr + 2k, 2\tr + 1k)5 2202.08676 (3k) \ge 4k, 1\tr + 3k, 2\tr + 2k, 3\tr + 1k, 1\tr + 2k, 2\tr + 1k + 2k, 2\tr + 1k)0.2-5.15 2103.02708 (2e, 2µ)0.2-5.0 2205.06709 (eµ)0.2-4.1 2205.06709 (er)0.2-4.1 2205.06709 (er)0.4-5.7 202.06075 (k + 0.5-3.6 1911.03947 (2j)0.6-5.0 5110.03949 (2µ + 2)0.6-4.8 2212.12604 (\tr + \tr \tr \tr 2k, 2\tr + 2k)(0.6-4.7 2112.03949 (2e + 2j)µ + \ge 1b)$	(2)



