New Physics Search Highlights at ATLAS and CMS

Shuo Han (韩朔)

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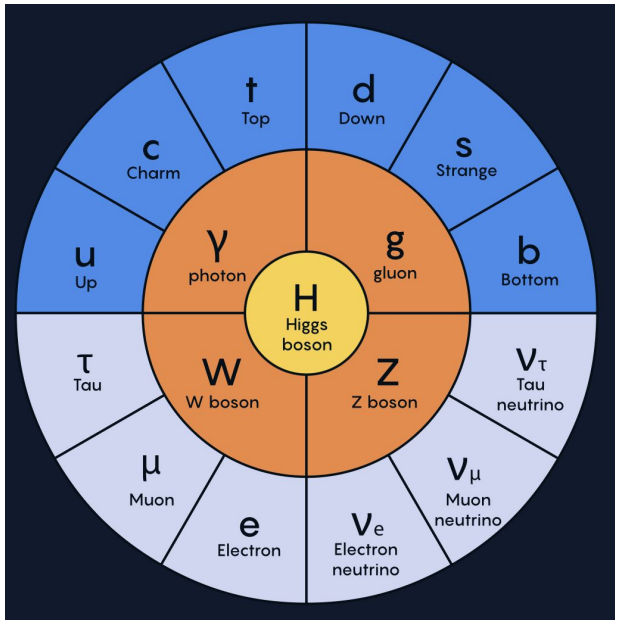
Introduction

The Theory



The SM is remarkably successful, major components are established, but..

The Puzzles

Big Questions

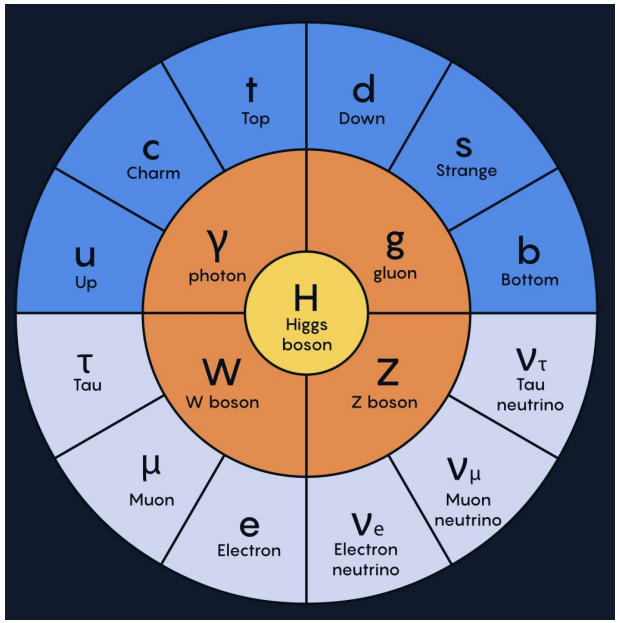
- Elementary vs. Composite
- New Forces
- Origin of Flavor
- Origin of Matter
- Unification
- Naturalness
- Origin of EWSB
- Dark Matter

Introduction

The Theory

The Puzzles

The Hypothesis



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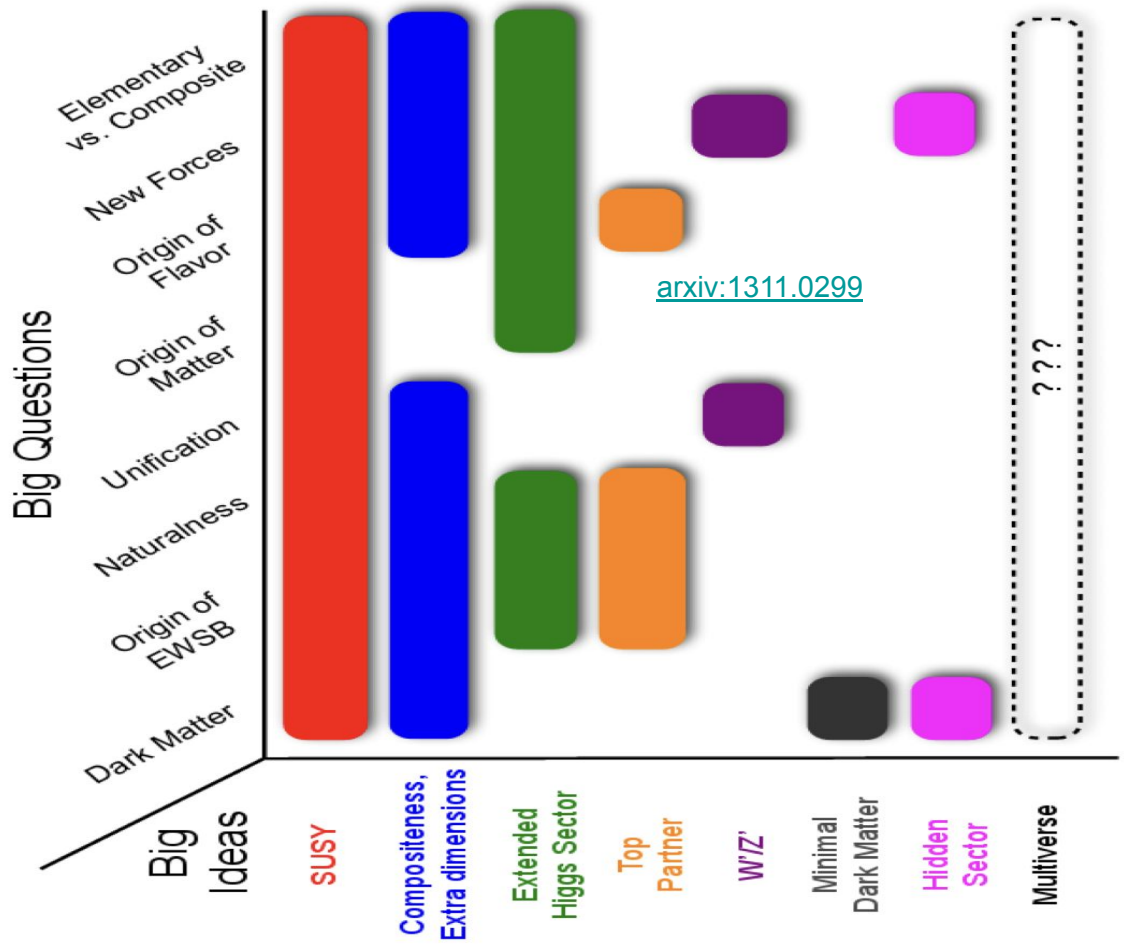

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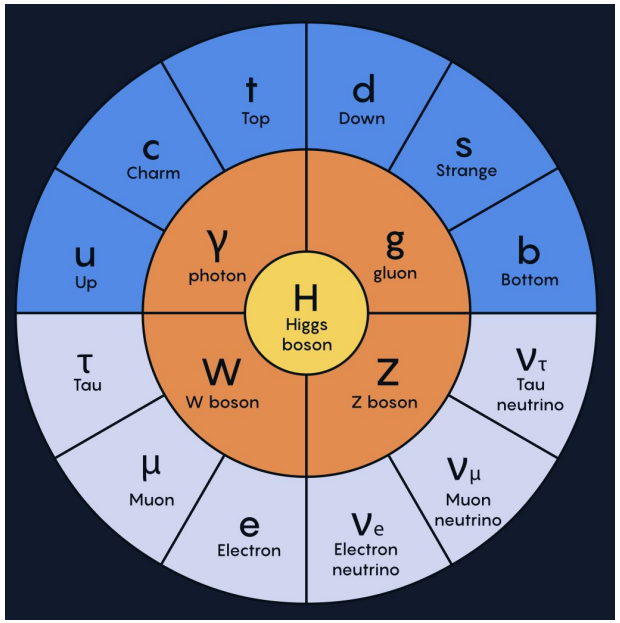
The Theory

The Puzzles

The Hypothesis

The Experiments



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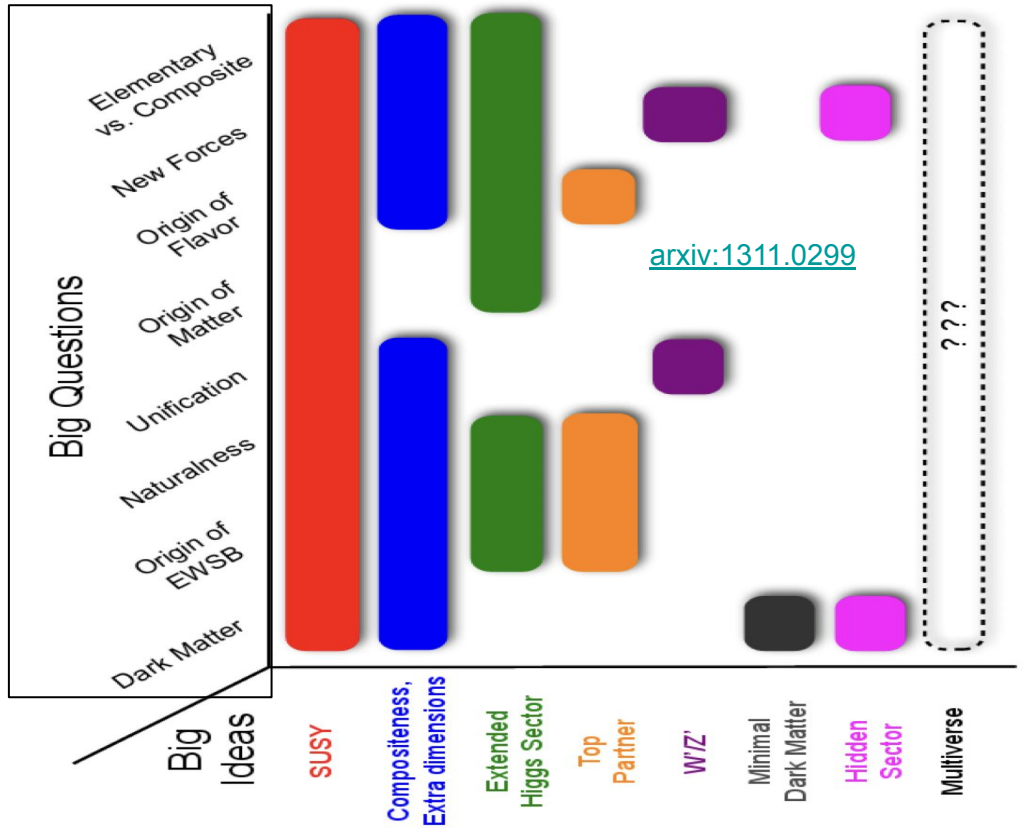
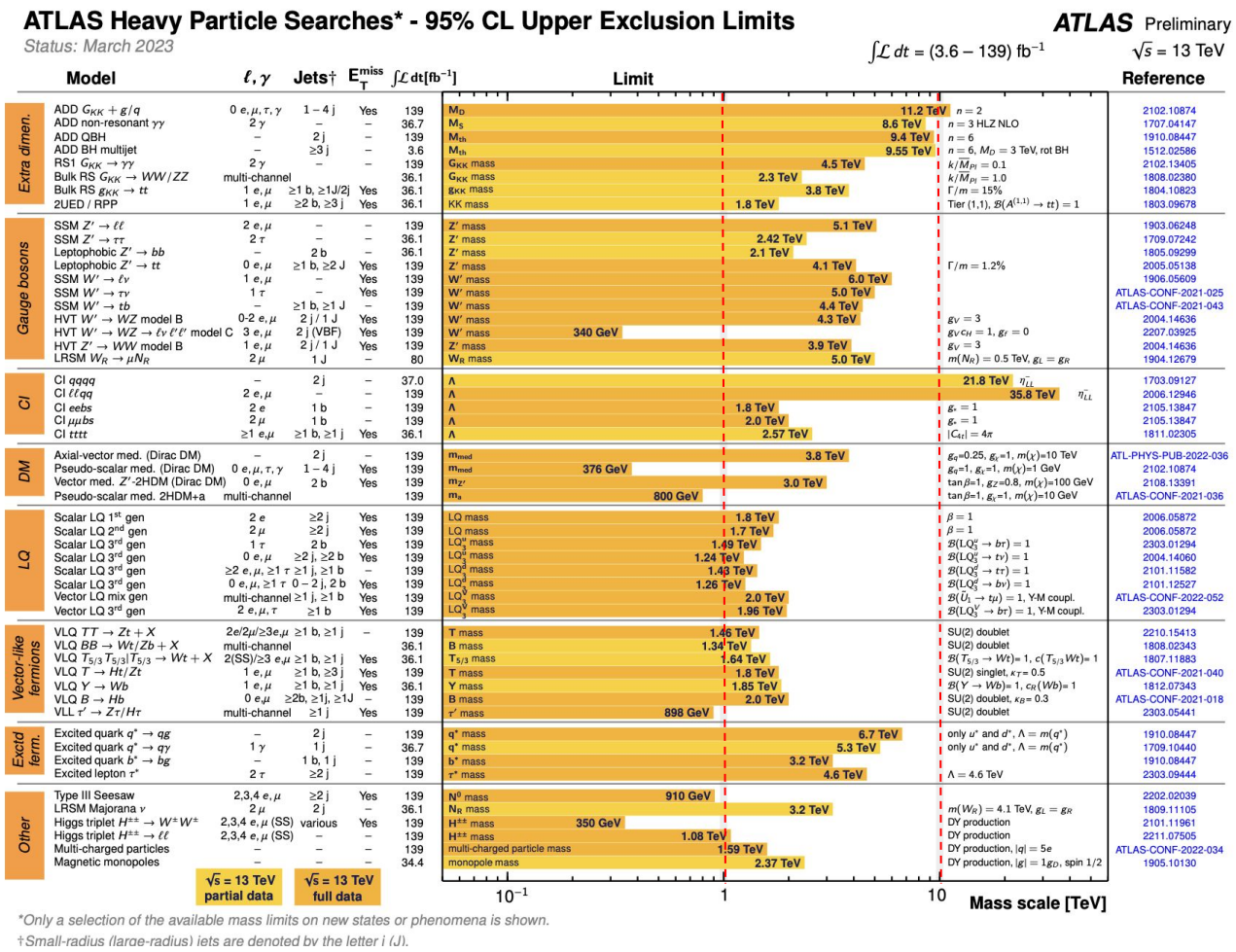


Precise Measurements of the SM (other talks)

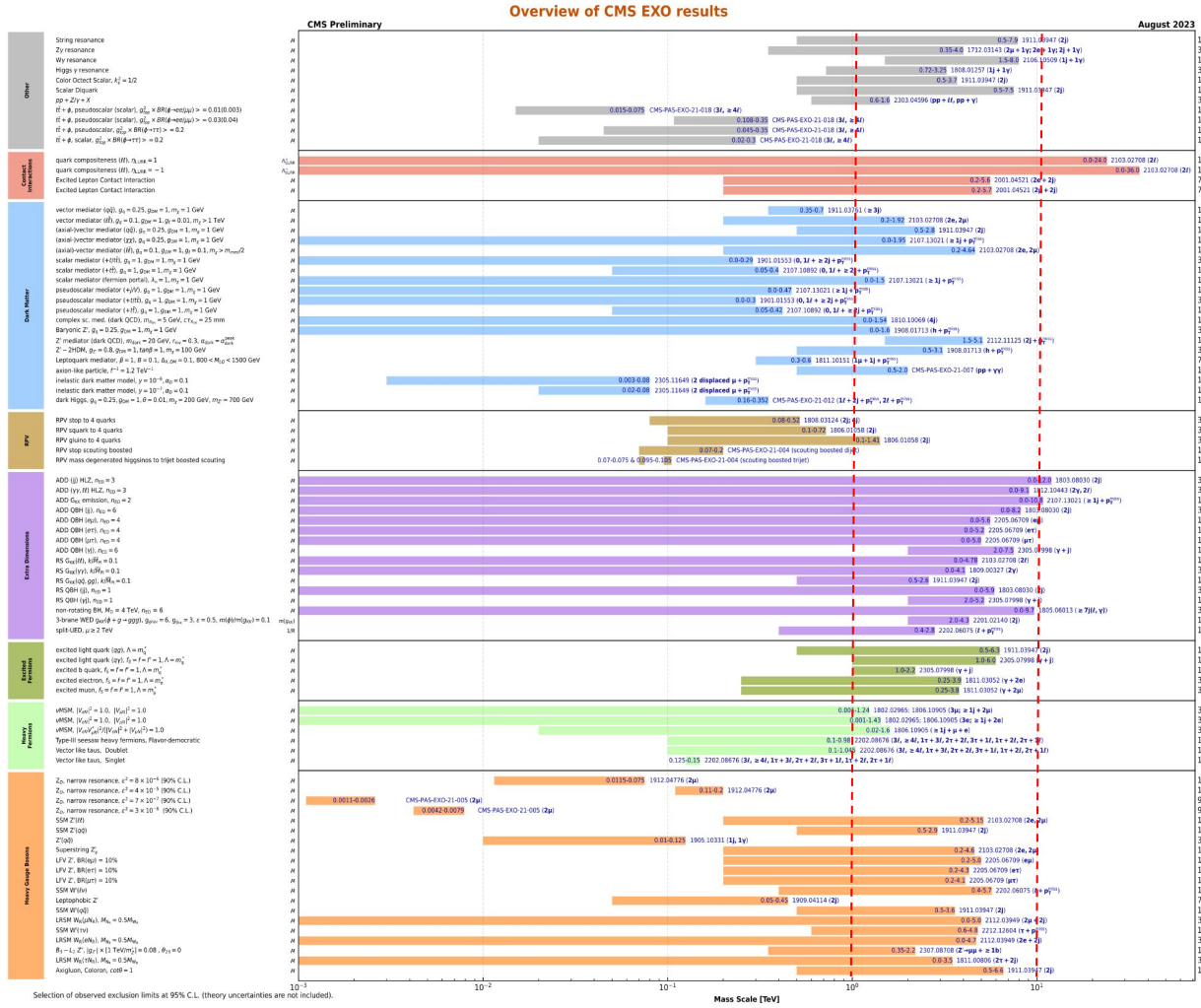
Searches for New Phenomenon:

1: Exotic searches
2: SUSY searches

The Exotic summary plots (2023)



[ATLAS summary plots]



[CMS summary plots]

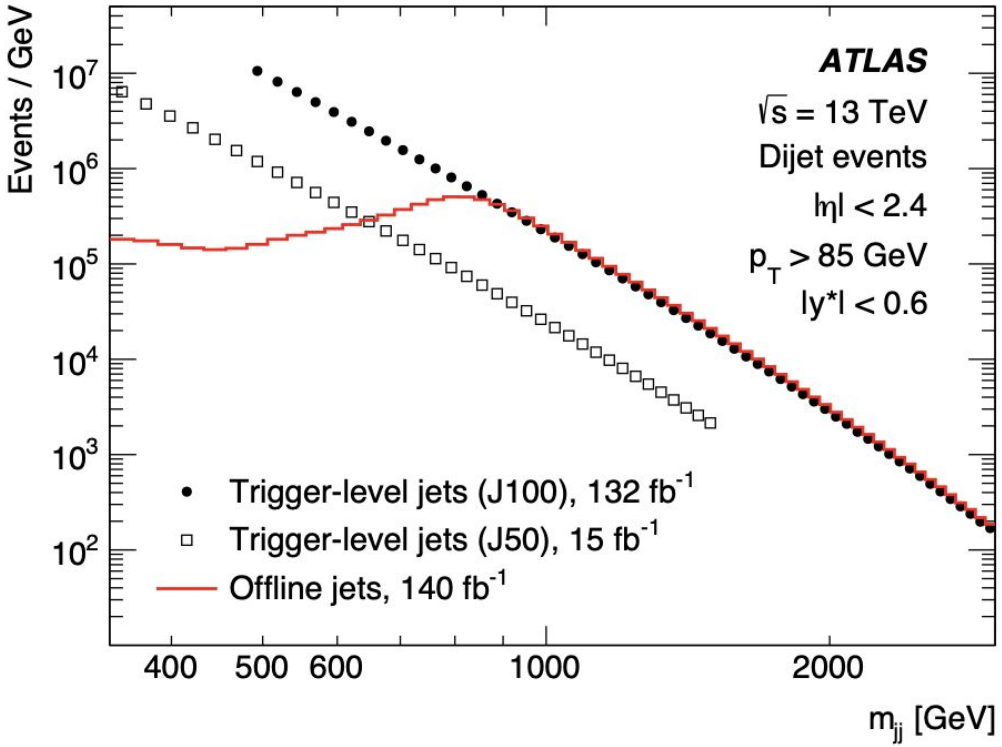
Highlights of New Exotic Results

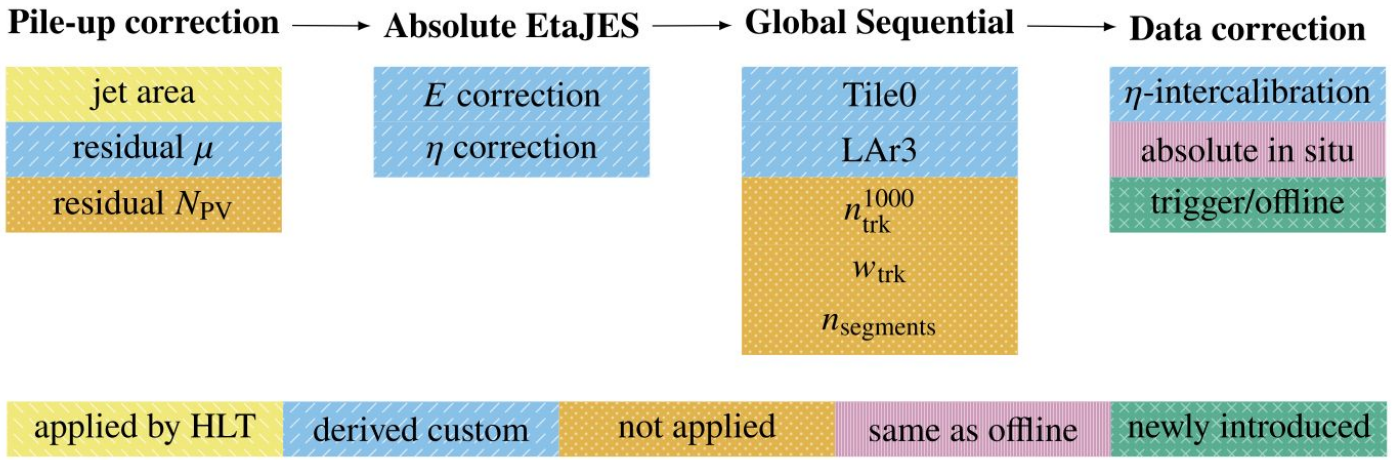
	CMS	ATLAS
Resonant searches	di-jet with data scouting EXO-23-004 (arxiv:2510.21641) di-jet with anomalous jet structure ROPP 88 (2025) 067802 pairs of di-jet resonace EXO-24-038 (arxiv:2507.17884) heavy Z' resonance to ττ/WW PRL 135 (2025) 061803 heavy neutral resonances to ττ PRD 111 (2025) 112004 *Heavy resonance in gWW JHEP 02 (2025) 199 H+Xγγ B2G-24-001 (arixv:2508.11494) X-ZH JHEP 02 (2025) 089 ZH/A-ttZ PLB 866 (2025) 139568 X-tg EPJC 85 (2025) 342	di-jet trigger level EXOT-2018-39 (arXiv:2509.01219) anomaly search in multilepton EXOT-2021-34 (arxiv:2508.19778) *semi-visible jets PRD 112 (2025) 012021 ttH/A-tttt EPJC 85 (2025) 573 Low-mass resonance + photon JHEP 01 (2025) 099
Long live particles (LLP)	b to LLP with muon detector EXO-24-004 (arxiv:2508.06363) VLL to LLP with muon detector JHEP 08 (2025) 156 LLP with ionization energy loss JHEP 04 (2025) 109 LLP with displaced jets ROPP 88 (2025) 037801 long-lived HNL with displaced lep-jet JHEP 02 (2025) 036	LLP with displaced jets EXOT-2022-17 (arxiv:2503.20445) Long-lived HNL in W JHEP 07 (2025) 196
Dark Matters (DM) Leptoquark Excited leptons Non-resonant	DM with tops JHEP 08 (2025) 085 t-channel Leptoquark dilepton EXO-22-013 (2503.20023) Excited τ JHEP 06 (2025) 006 Vector-Like top B2G-23-009 non-resonant bbll/bsll EXO-23-010 (arxiv:2506.13565) anomalous jet + Hbb B2G-2024-015 (2509.13635)	*Dark Higgs with bb PRL 134 (2025) 121801 Dark photon in leptons EPJC 85 (2025) 335 *Emerging jets EXOT-2018-20 (arXiv:2510.12347), ROPP 88 (2025) 097801 Prompt HNL in W EXOT-2019-35 (arxiv:2508.20929) *Leptoquark with lep-jet EXOT-2024-12 (arxiv:2507.03650) VLQ in W+b (lep) EXOT-2018-60 (arxiv:2506.15515) VLQ in W+b (had) JHEP 02 (2025) 075 VLL in τ+b EXOT-2022-27 (arxiv:2503.22581) VLL in leptons JHEP 05 (2025) 075 Vector-Like top PRD 111 (2025) 012012 High-mass ττ JHEP 10 (2025) 54

~30 CMS PAS not included (e.g *HIG-24-014, B2G-24-007, B2G-24-010, B2G-24-009, B2G-24-003)
resonant HH / HHH searches are not included
End of 2024 results not included

Resonances search with trigger-level analysis

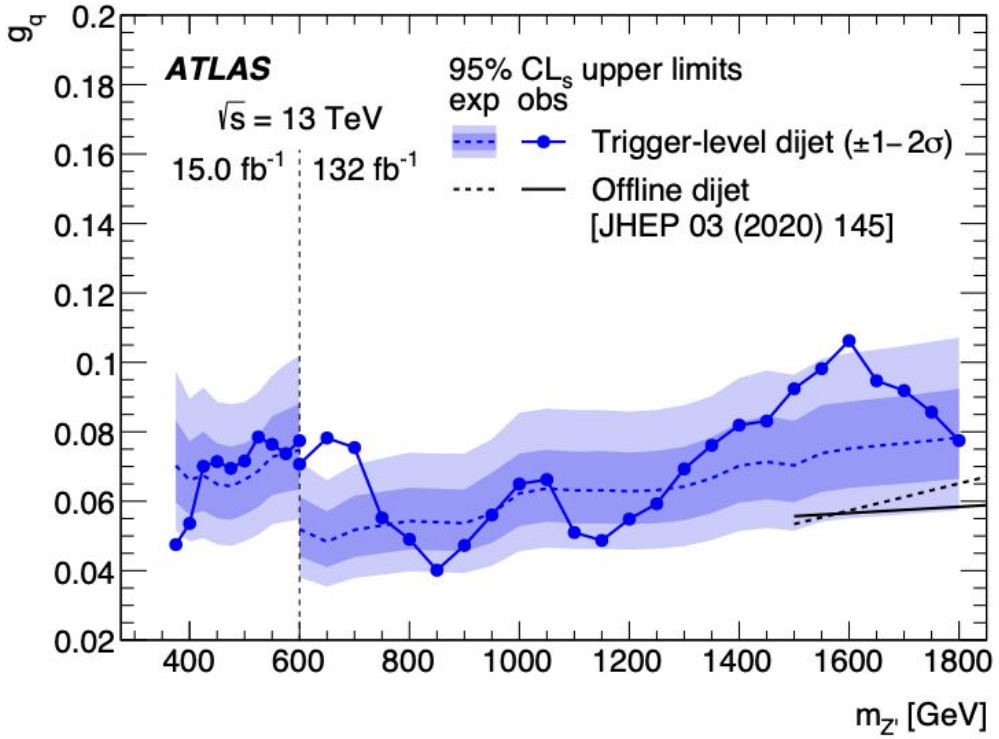
- Trigger-level analysis makes it possible to utilize the **data rejected by offline triggers**
- ATLAS searched for dijet resonances in the 375–1800 GeV range with 132 fb^{-1} of 13 TeV data, extending sub-TeV coverage via L1Topo and low-threshold triggers EXOT-2018-39 (arXiv:2509.01219)
- Improved trigger-jet calibration, and a single-function, data-driven background model.



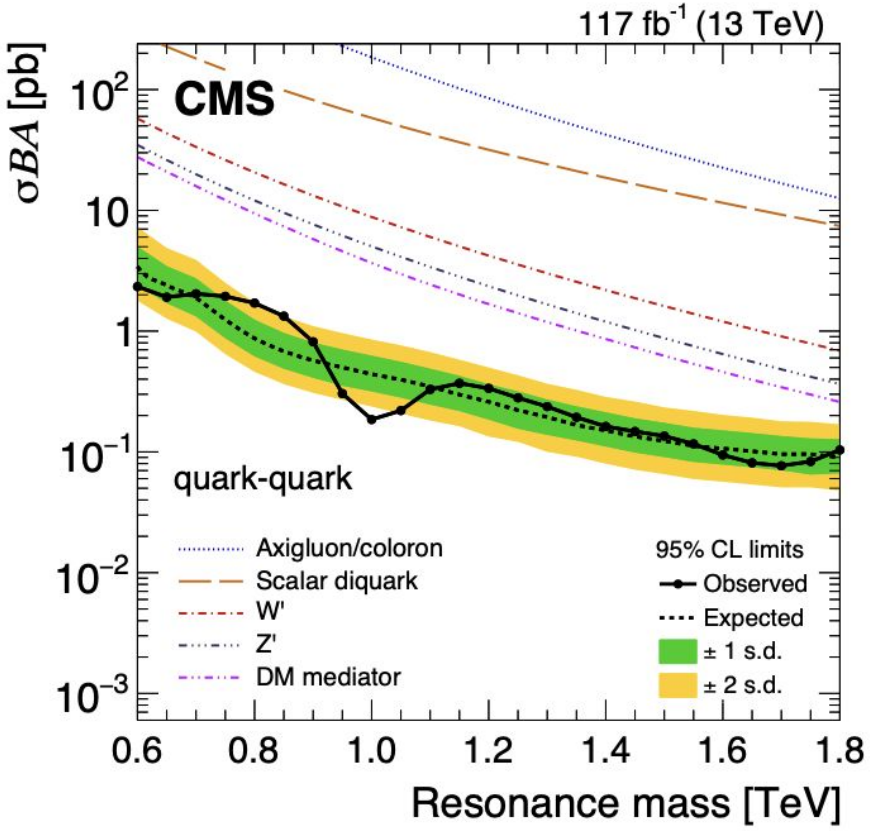


Resonances search with trigger-level analysis

- No significant localized excess is observed (global p-values: 0.55 for J50 and 0.27 for J100)
- However, it sets limits in lower mass range, superseding the offline di-jet result
- CMS presented similar study using scouting data, ans set limits in a sub-TeV mass range too



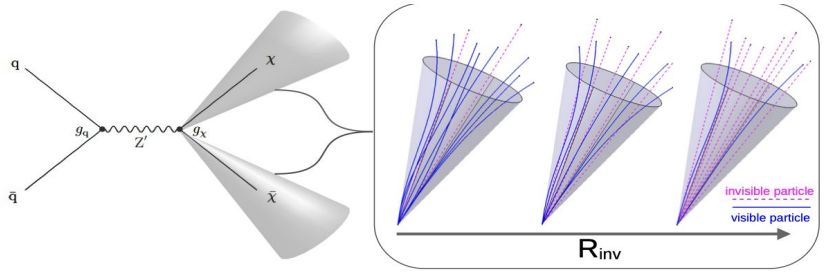
EXOT-2018-39 (arXiv:2509.01219)

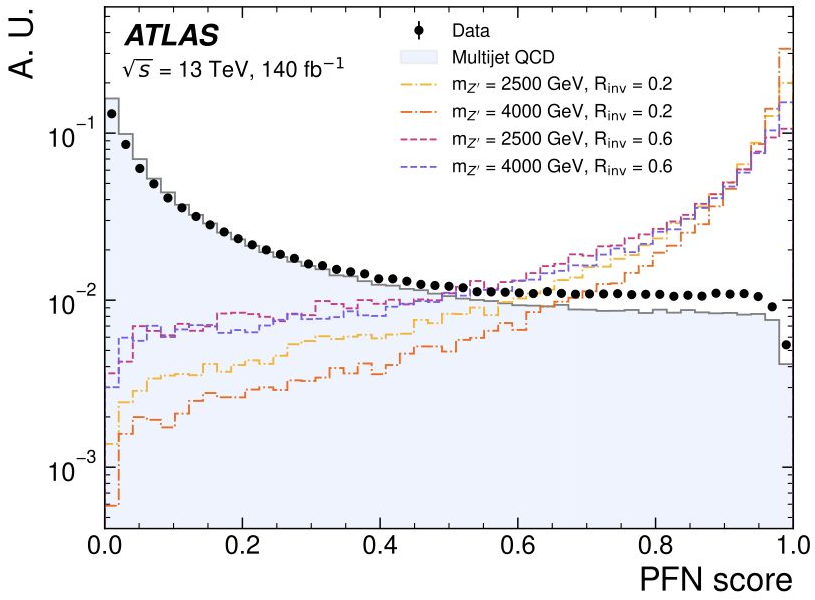


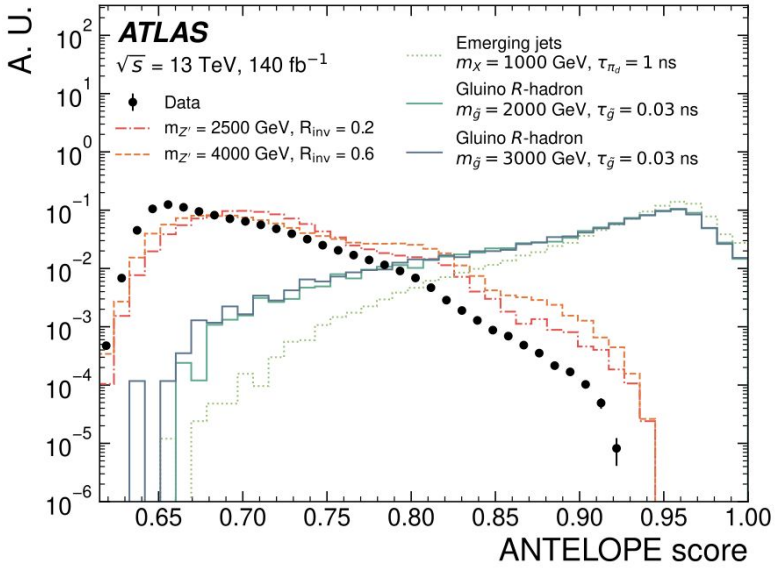
EXO-23-004 (arxiv:2510.21641)

Anomaly search with machine learning

- Anomaly search with ML is crucial to uncover **new physics with unconventional signatures**
- ATLAS searches for semi-visible jets from a strongly-coupled dark sector via a Z′ mediator
- The analysis uses ANTELOPE for semi-visible jets, which first learns jet features with a PFN, then performs anomaly detection in latent space using an auto-encoder [PRD 112 (2025) 012021]

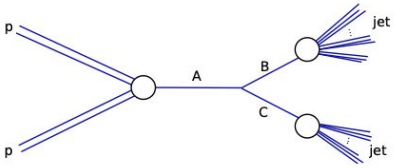


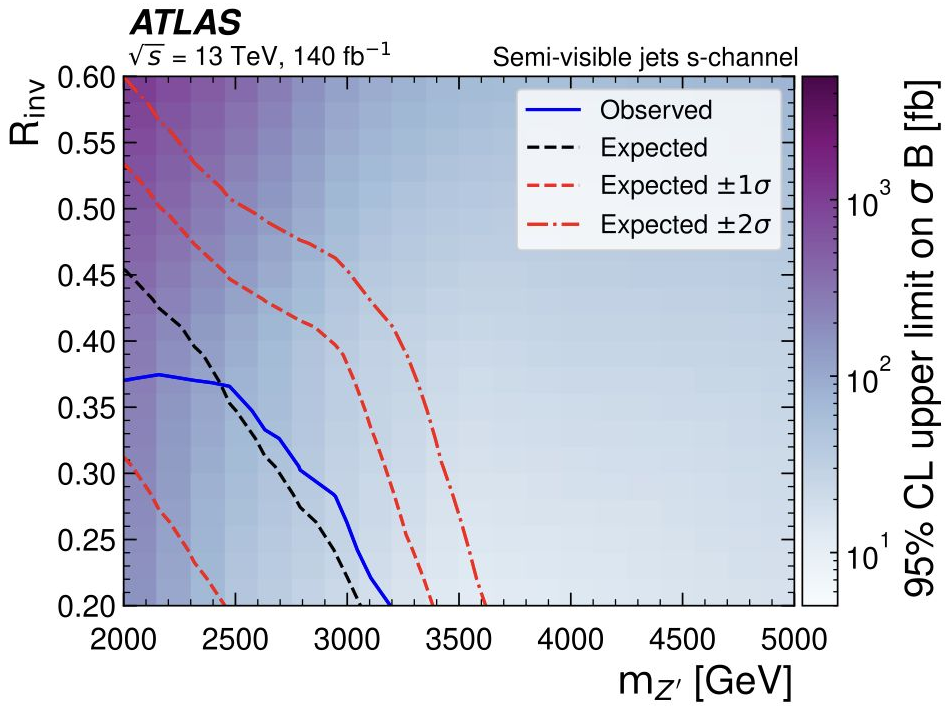




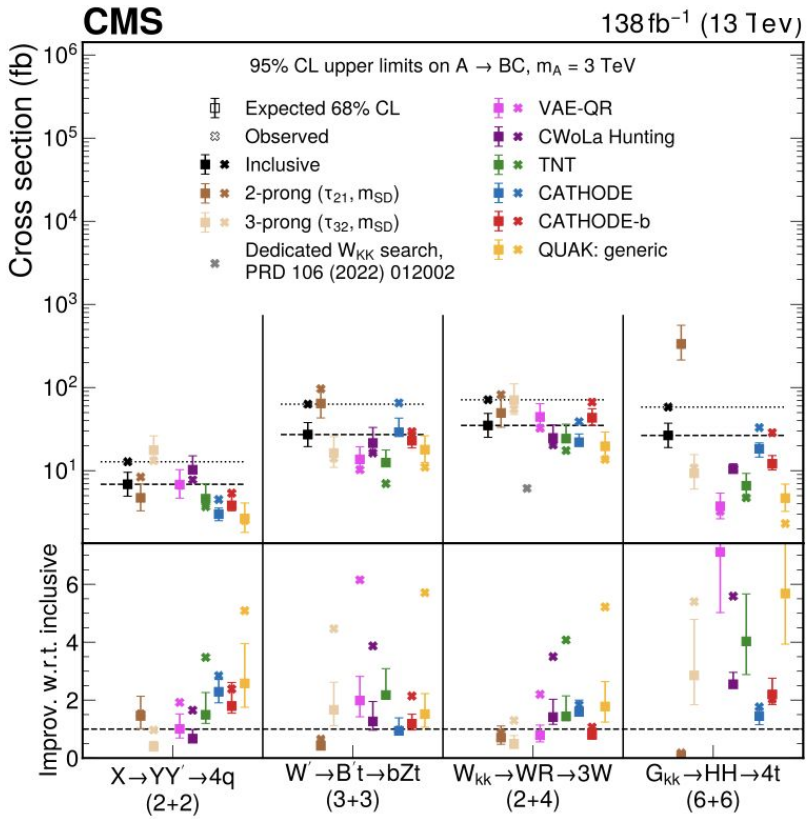
Anomaly search with machine learning

- No excess observed in semi-visible jet search; Z′ masses 2.0–3.2 TeV excluded at 95% CL for invisible fraction (Rinv) = 0.2 – 0.37
- CMS also presents an anomaly search for di-jet resonance with jet substructure
  - 3 ML strategies are studies, and results are presented with all methods





PRD 112 (2025) 012021

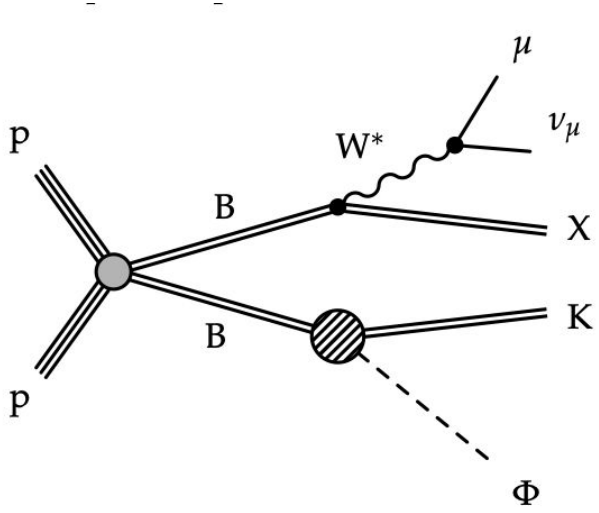


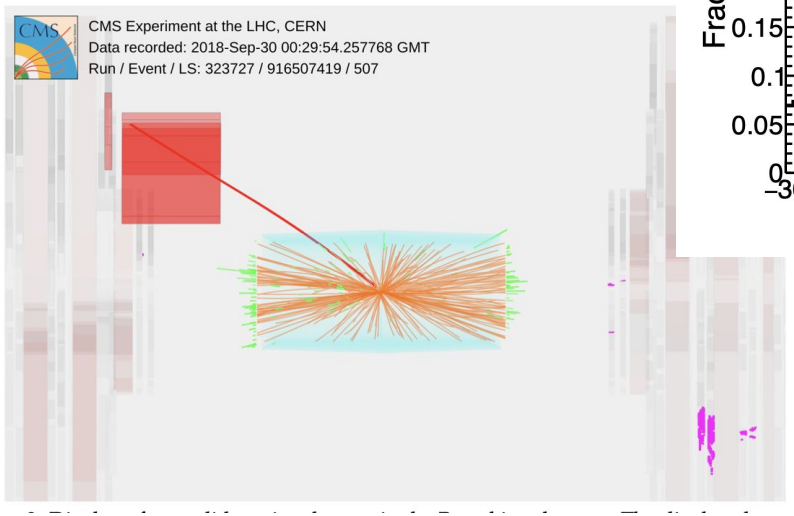
ROPP 88 (2025) 067802

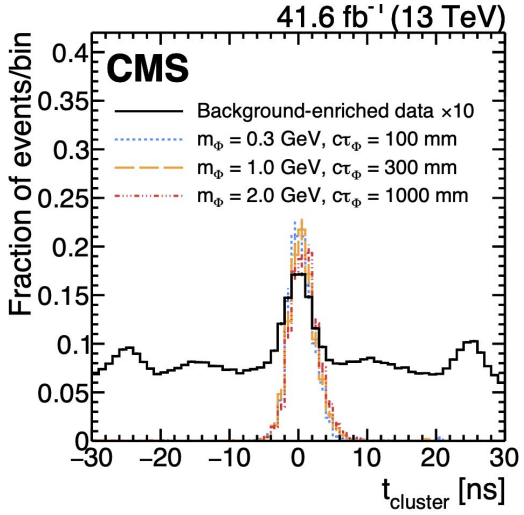
Long live particle searches with detector timing

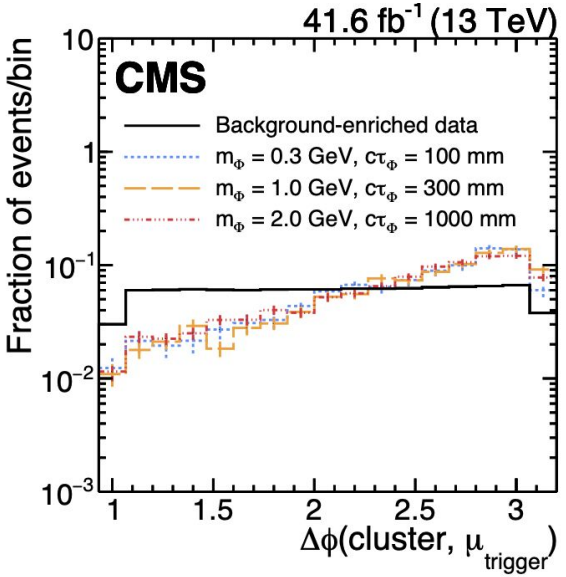
- BSM hypothesis predicting long-live particles, searching for LLP required to utilize the detector timing
- CMS performs a search for b hadron decays to long-lived particles using end-cap muon detector
  - relies on CMS CSC cluster timing (5ns resolution) and hit topology (400-500 um resolution)

EXO-24-004 (arxiv:2508.06363)



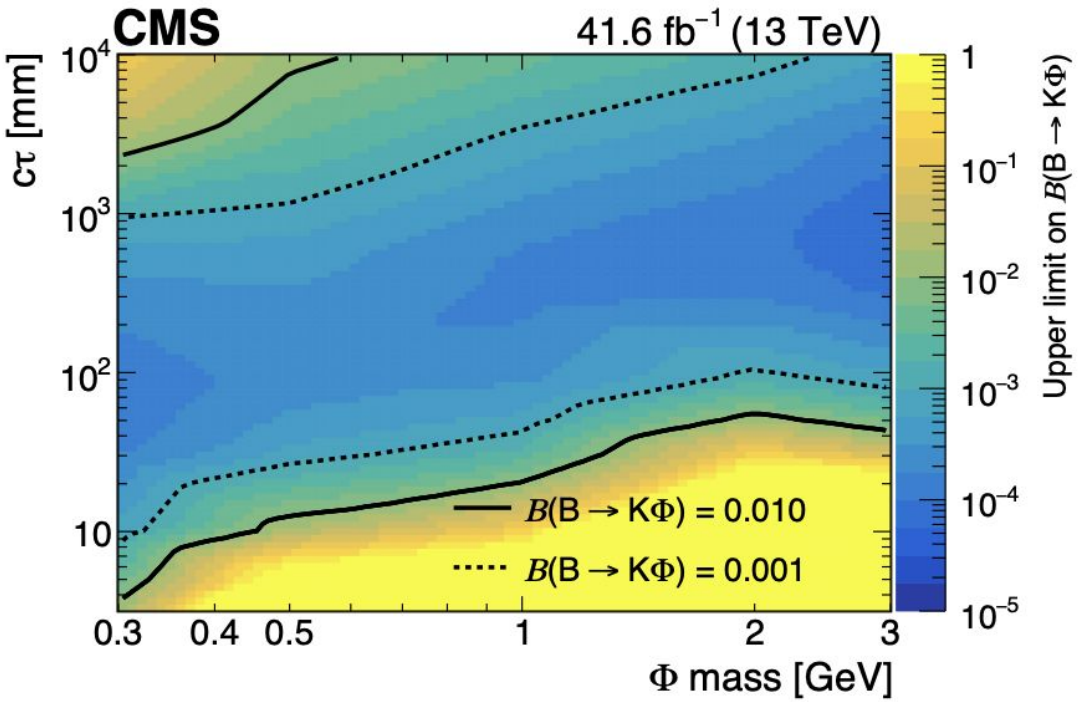






Long live particle searches with detector timing

- No excess found and limits are set on decay length and new particle mass
- The previous studies has covered various types of LLP using tracker, calorimeter and muon system



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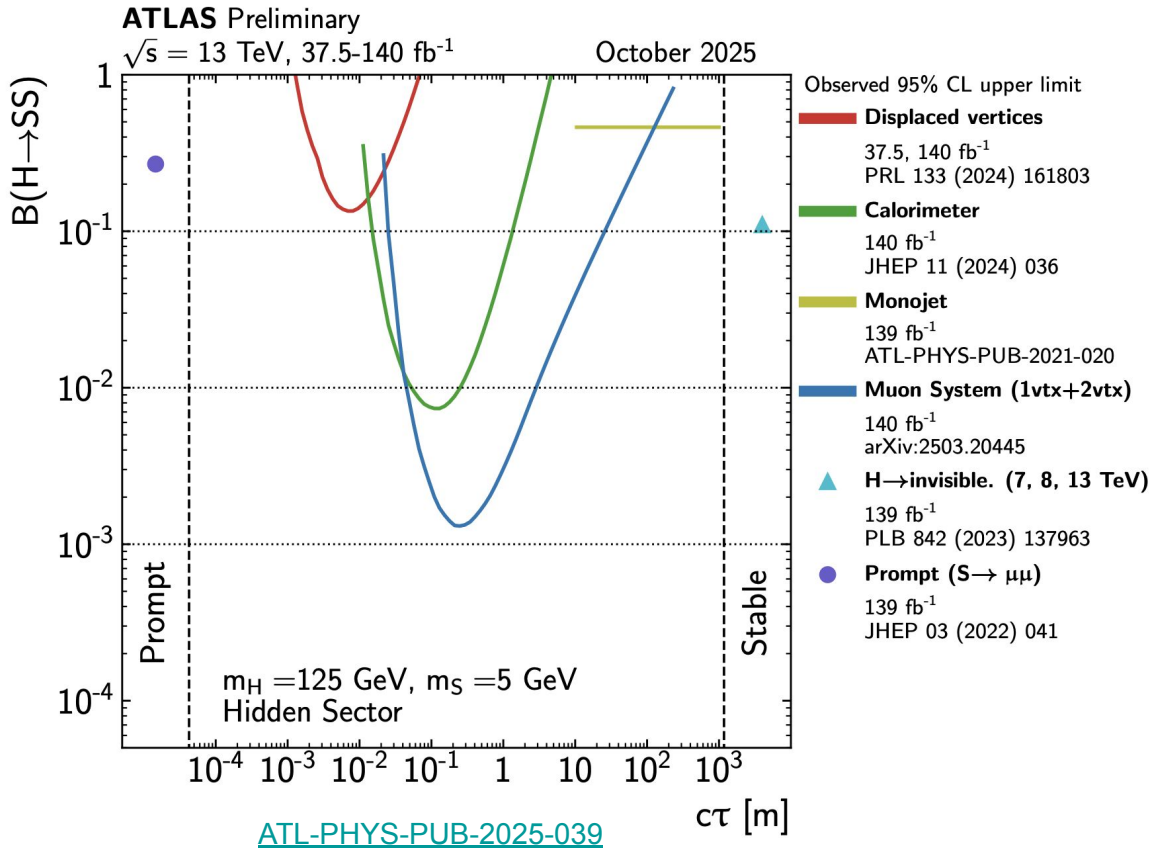
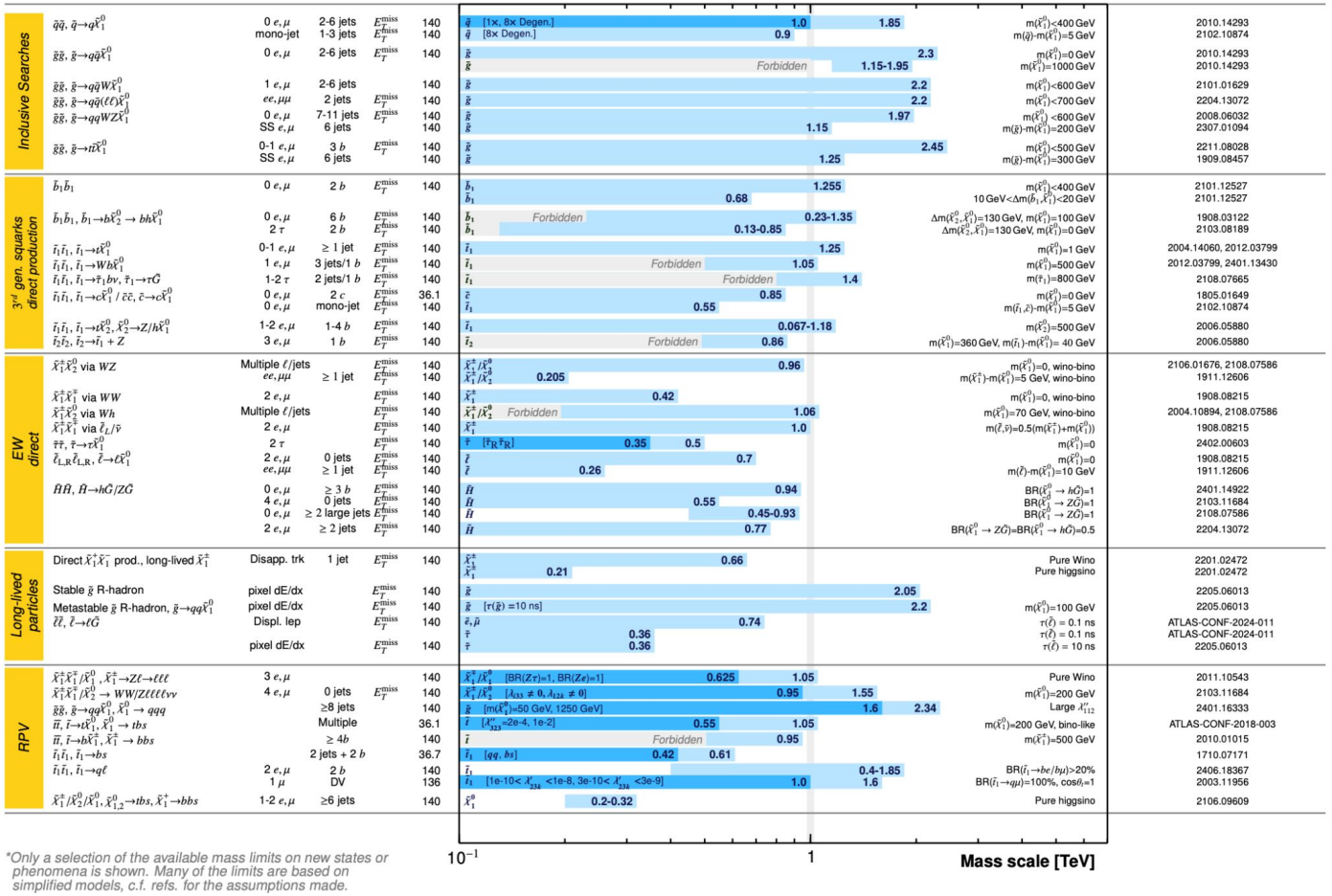
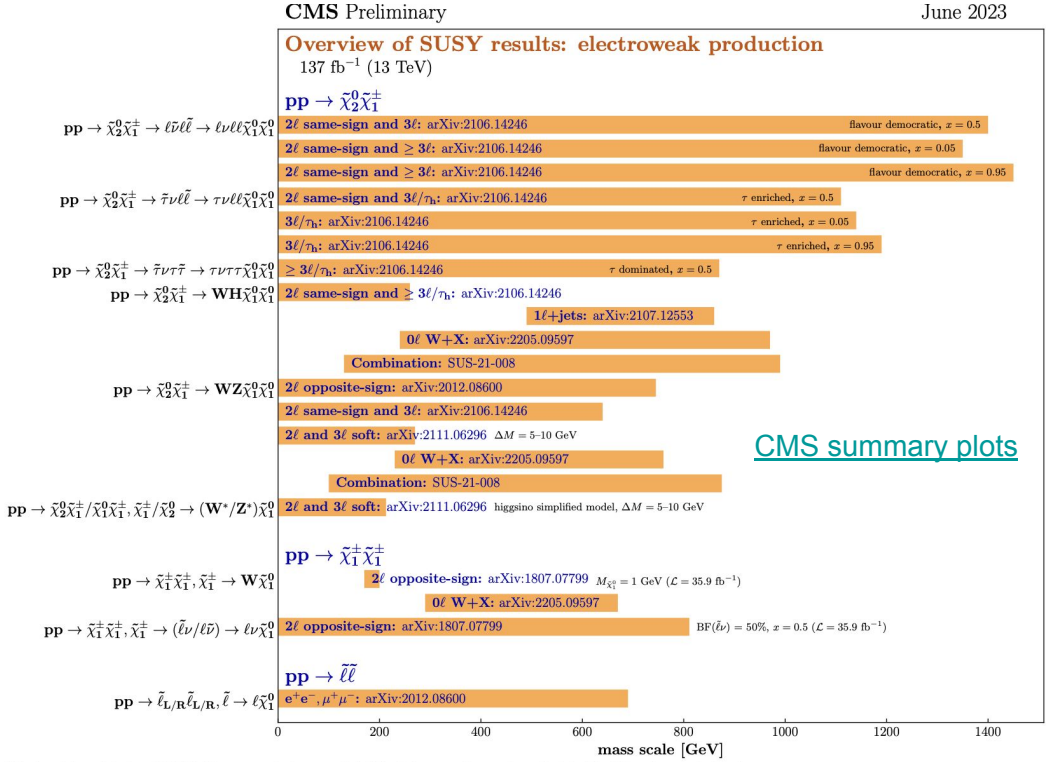


ATL-PHYS-PUB-2025-039

The SUSY summary plots (up to 2024)

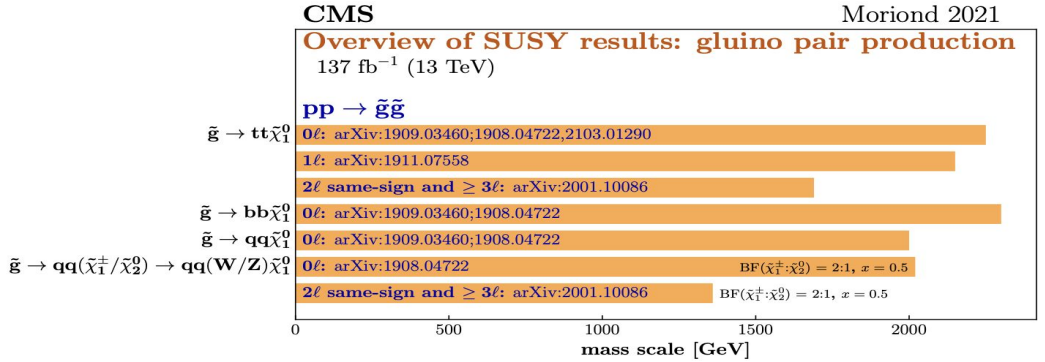


ATLAS summary plots



CMS summary plots

Selection of observed limits at 95% C.L. (theory uncertainties are not included). Probe **up to** the quoted mass limit for light LSPs unless stated otherwise. The quantities ΔM and x represent the absolute mass difference between the primary sparticle and the LSP, and the difference between the intermediate sparticle and the LSP relative to ΔM, respectively, unless indicated otherwise.



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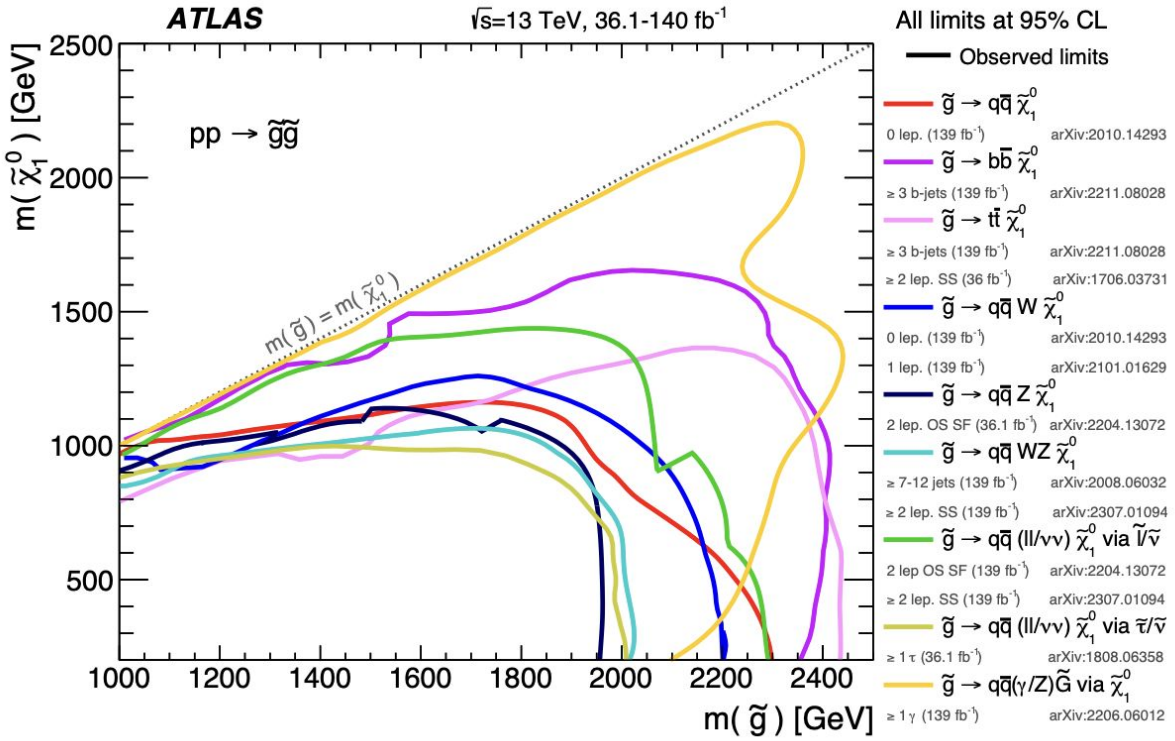
Highlights of New SUSY Results

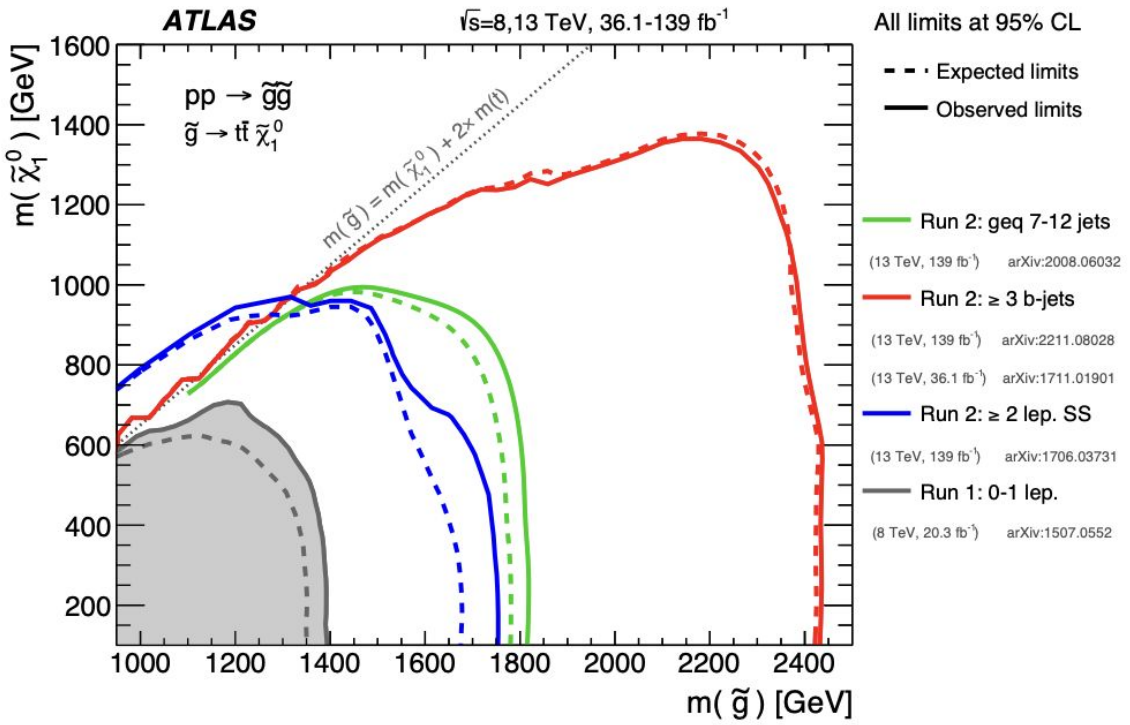
	CMS	ATLAS
Compressed	Compressed general search SUS-23-003 (arXiv:2508:13900)	compressed electroweakinos in VBF JHEP 12 (2024) 116
Dark Matter (DM), 2HDM + S / a	DM with b + ll SUS-23-018 (arxiv:2510.12396) H to light pseudoscalar SUS-24-002 (arxiv:2508.06947) DM with Hττ SUS-23-012 (arXiv:2506.04431) DM via FCNC single-top JHEP 09 (2025) 141 Heavy Higgs to bb with 2HDM JHEP 06 (2025) 144 b-jets + MET in 2HDM+a JHEP 02 (2025) 050	SUSY review Phys. Rep. 1116 (2025) 261-300
Charm-tagged, GMSB higgsino search LLP..		stop/scharm→c $\tilde{\chi}$ JHEP 02 (2025) 193 displaced leptons PRD 112 (2025) 012016 GMSB higgsino search in bbγγ PLB 856 (2024) 138938
RPV	stop in RPV SUS-23-001 (arXiv:2506:08825) RPV with jet-scaling in mult-L SUS-23-015 (arxiv:2503.06726)	stop in RPV PRD 110 (2024) 092004

9 CMS PAS not included
Only 2025 results for CMS, and post-Moriond 2024 results for ATLAS

SUSY review of ATLAS

- ATLAS Run2 delivers broad, state-of-the-art SUSY limits across RPC, RPV, LLP scenarios
- Phys. Rep. 1116 (2025) 261-300 summarize the Run2 results





Limits on gluino - LSP mass

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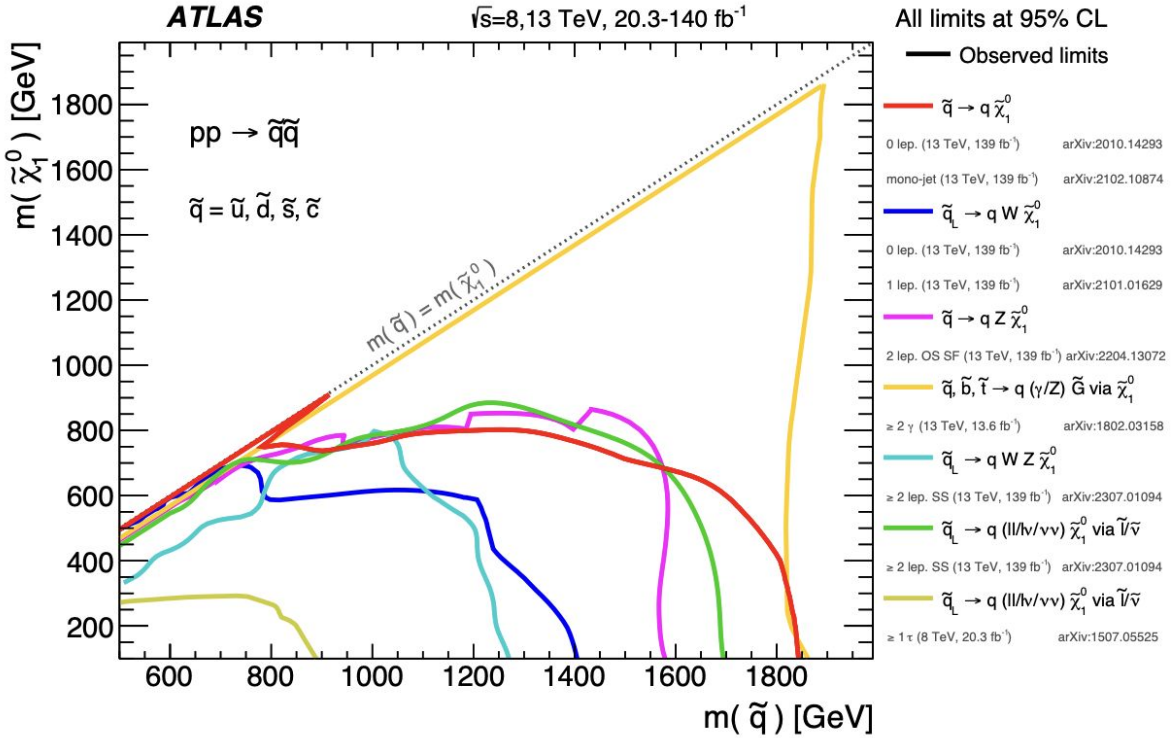
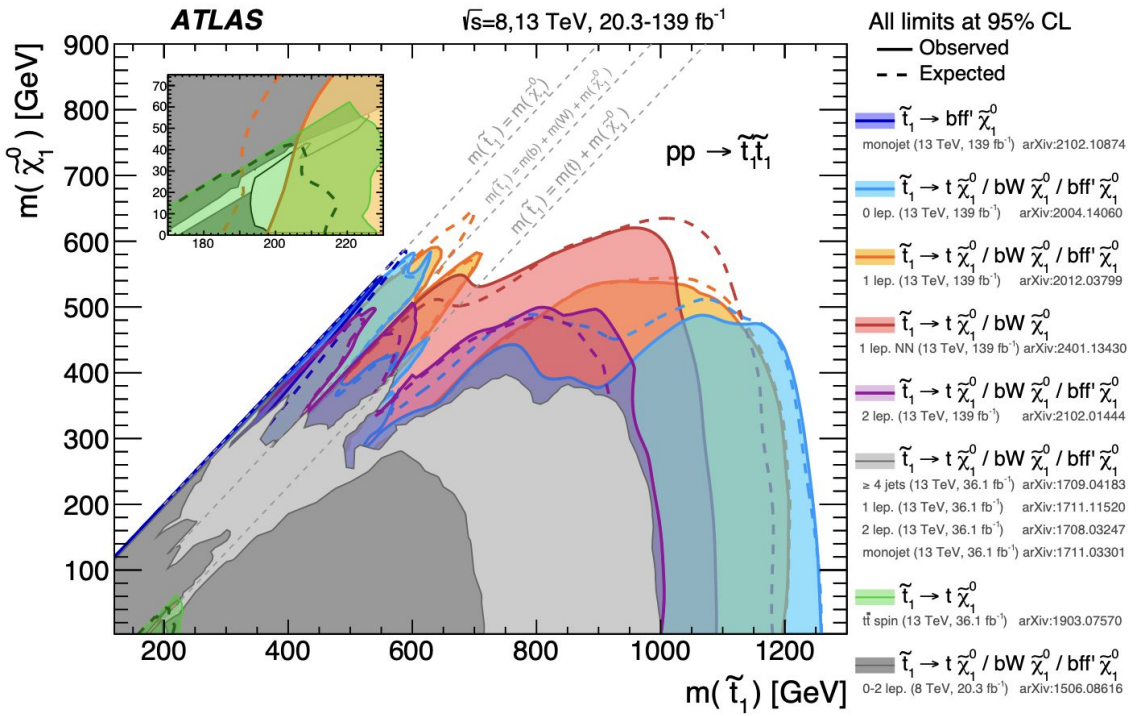


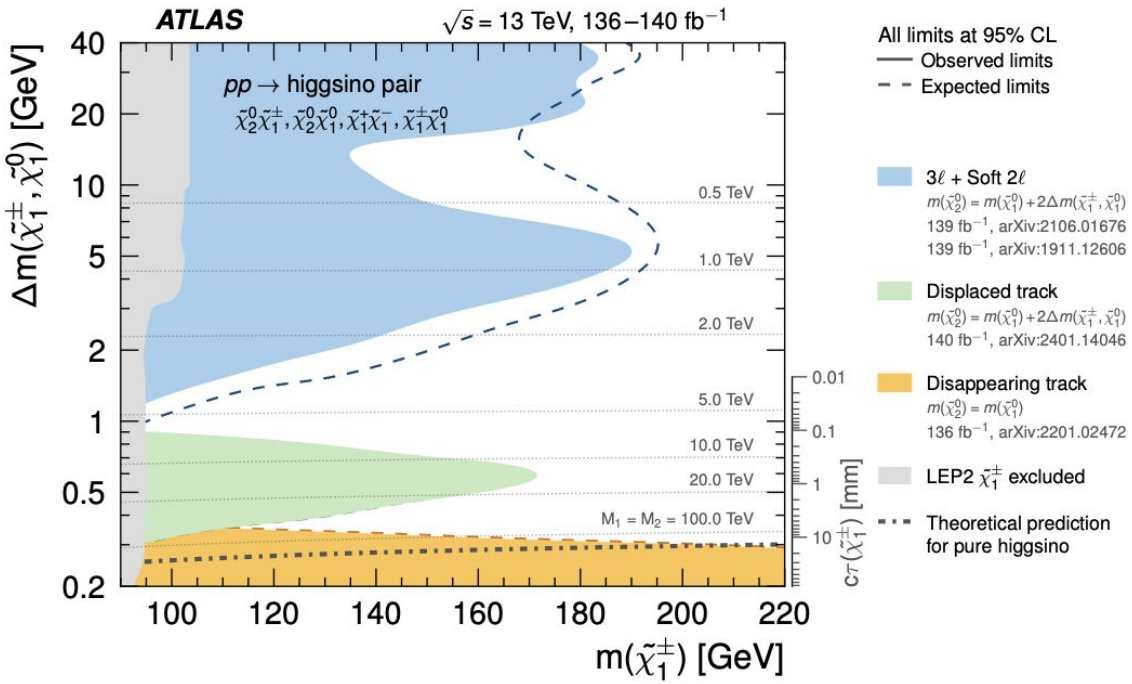
Limits on squark - LSP mass



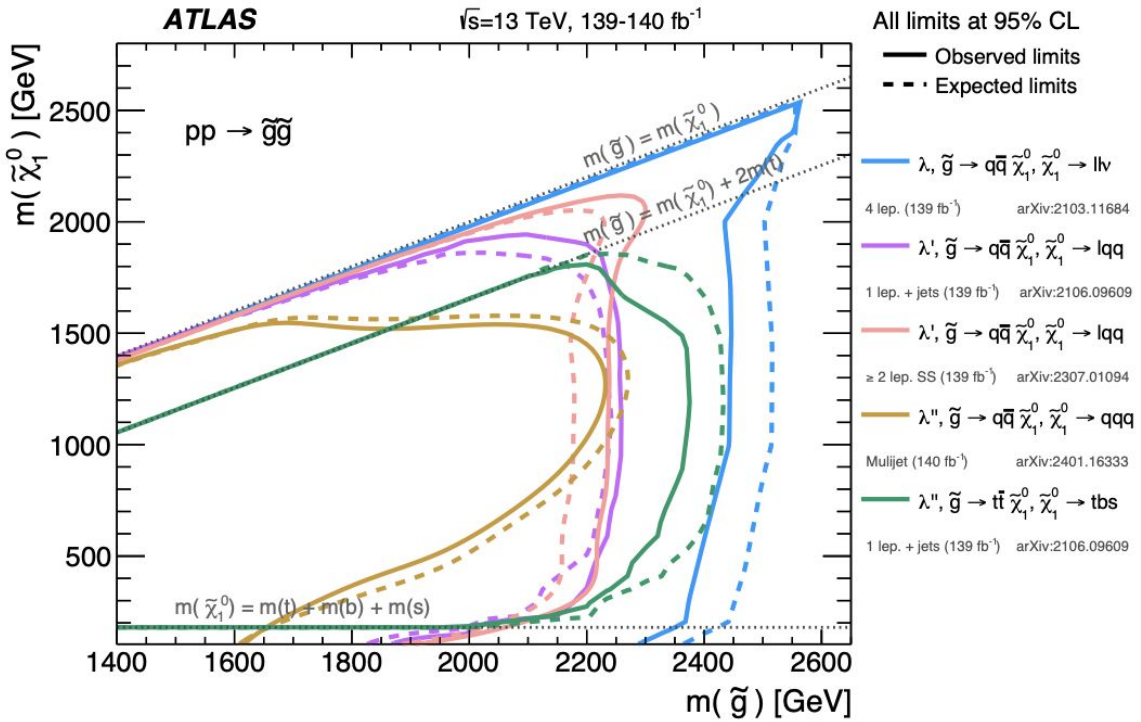
Limits on stop - LSP mass

SUSY review of ATLAS

- ATLAS Run2 delivers broad, state-of-the-art SUSY limits across RPC, RPV, LLP scenarios
- Phys. Rep. 1116 (2025) 261-300 summarize the Run2 results
- more models / results in the paper



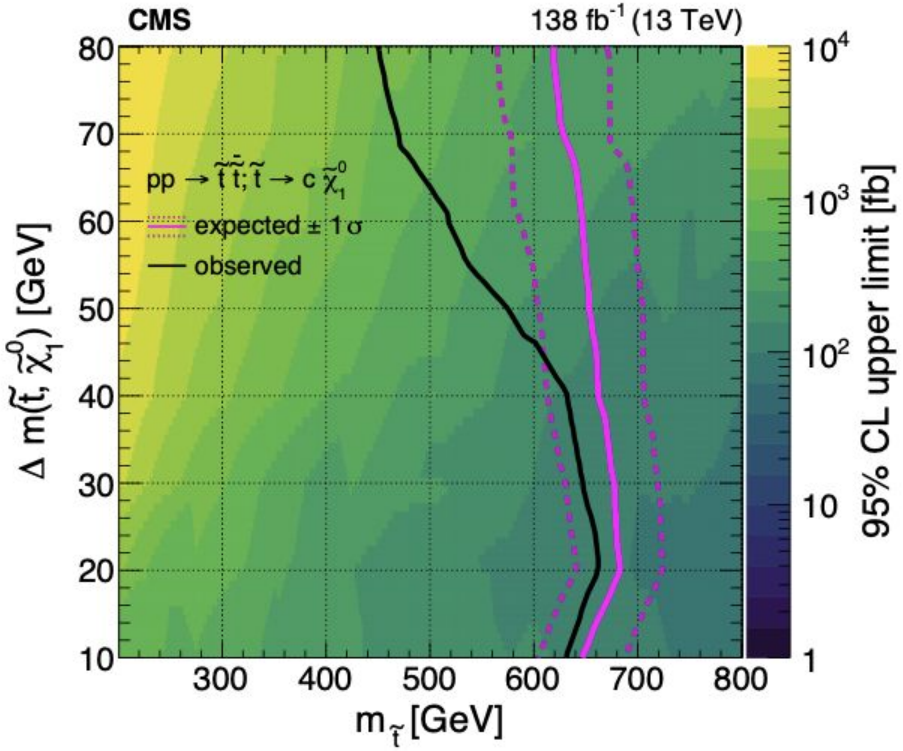
Limits on higgsino pair



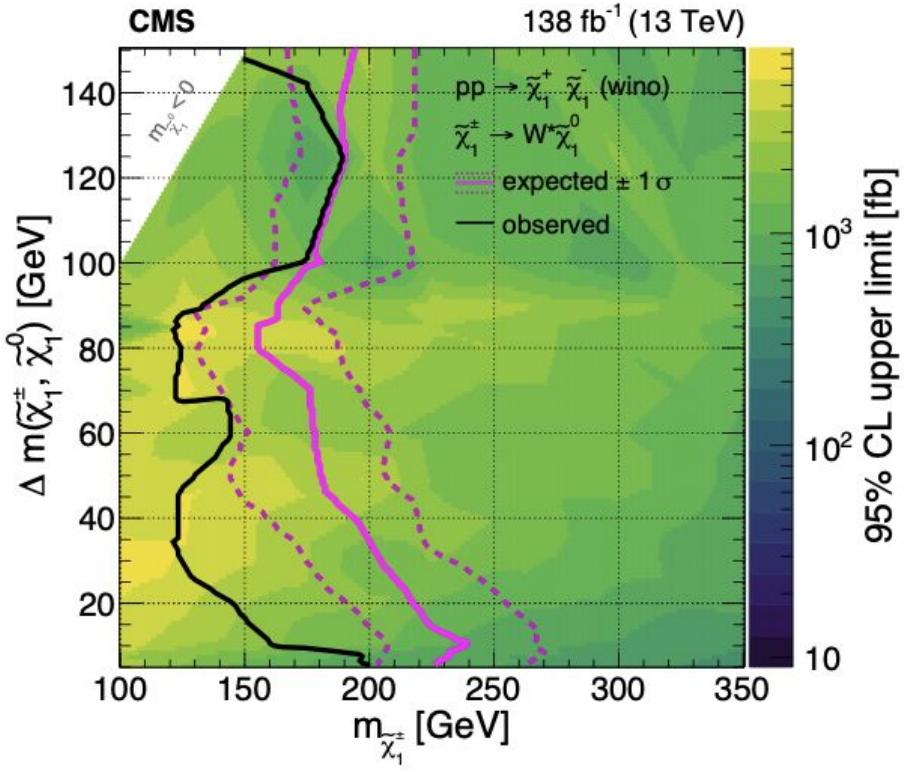
Limits on gluonio - LSP mass

CMS RPC SUSY general search

- CMS also presents general search for RPC SUSY SUS-23-003 (arXiv:2508:13900)
- Limits are set for electroweakinos, sleptons, and top squarks



Limits on stop - LSP mass

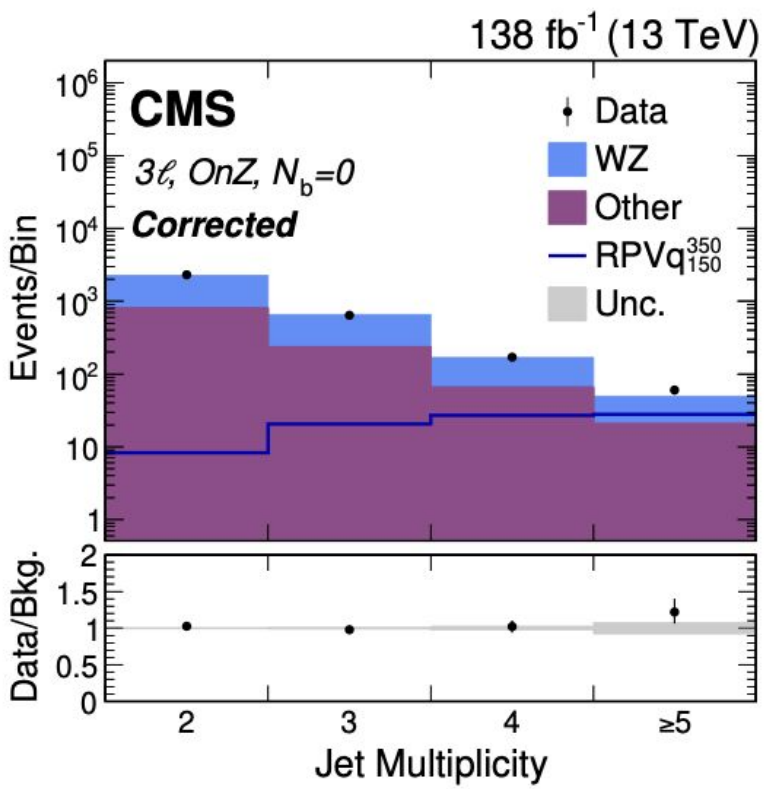


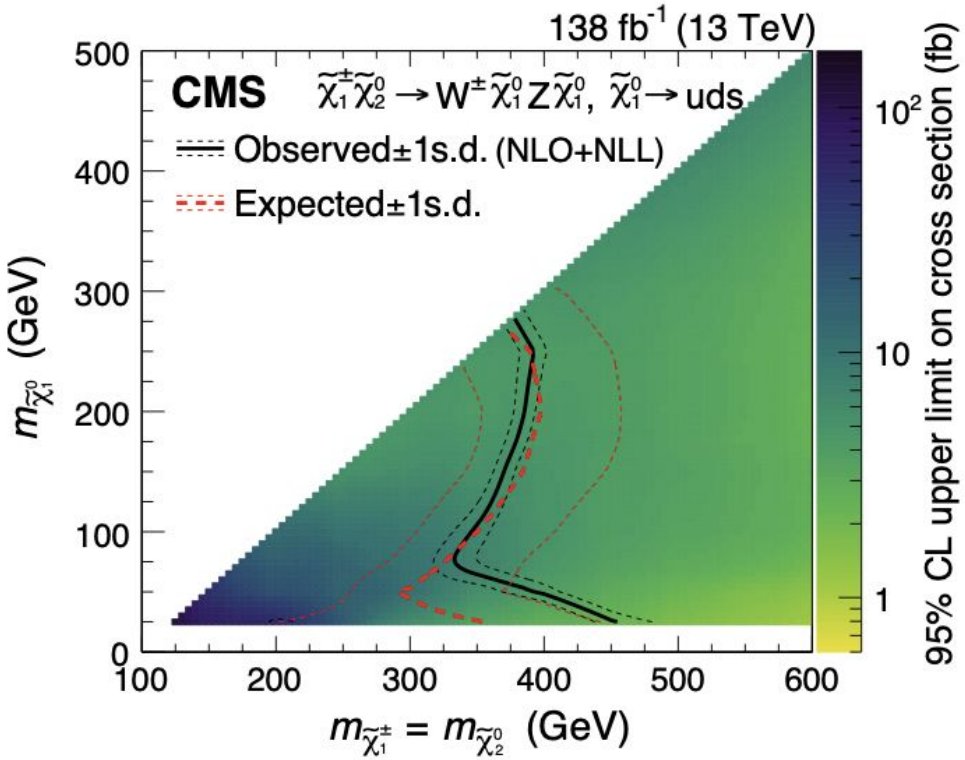
Limits on chargino-neutralino production

First Jet-scaling search in multilepton events

- CMS performed the first jet-scaling search for RPV in multilepton events, and finds no deviation
- Solves the simulation difficulty by a data-driven jet-scaling strategy to accurately model high-multiplicity jets in multilepton events
- Constrains electroweak RPV SUSY with prompt hadronic decays.

SUS-23-015 (arxiv:2503.06726, submitted to PRL)





Summary

- Searches for new phenomena are a critical of the LHC physics program

- From a theoretical perspective, testing hypotheses such as SUSY, compositeness, and extended Higgs sectors is essential for addressing the puzzles of the Standard Model

- From an experimental perspective, SUSY & Exotic searches have motivates significant advances in analysis strategies, including the use of scouting data, anomaly detection with unsupervised machine learning, and improved detector timing and spatial resolution

- Both ATLAS and CMS have been highly productive in 2024–2025 with many new results.
- More details can be found in the parallel session presentations.