SUSY AND DARK MATTER SEARCHES IN ATLAS AND CMS

T. Lari, INFN Milano

on behalf of the ATLAS and CMS Collaborations

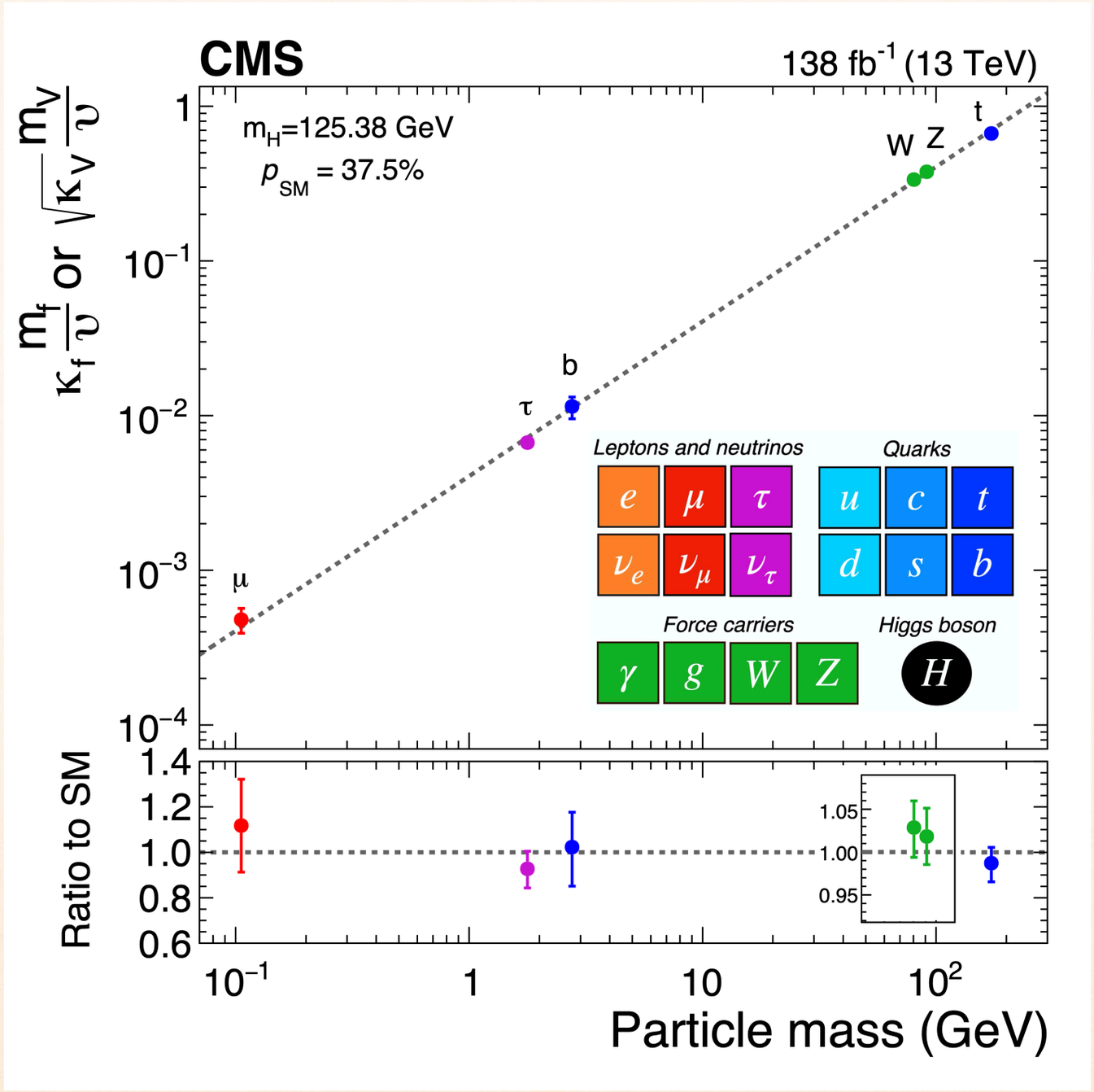
EXECUTIVE SUMMARY

We haven't found Supersymmetry

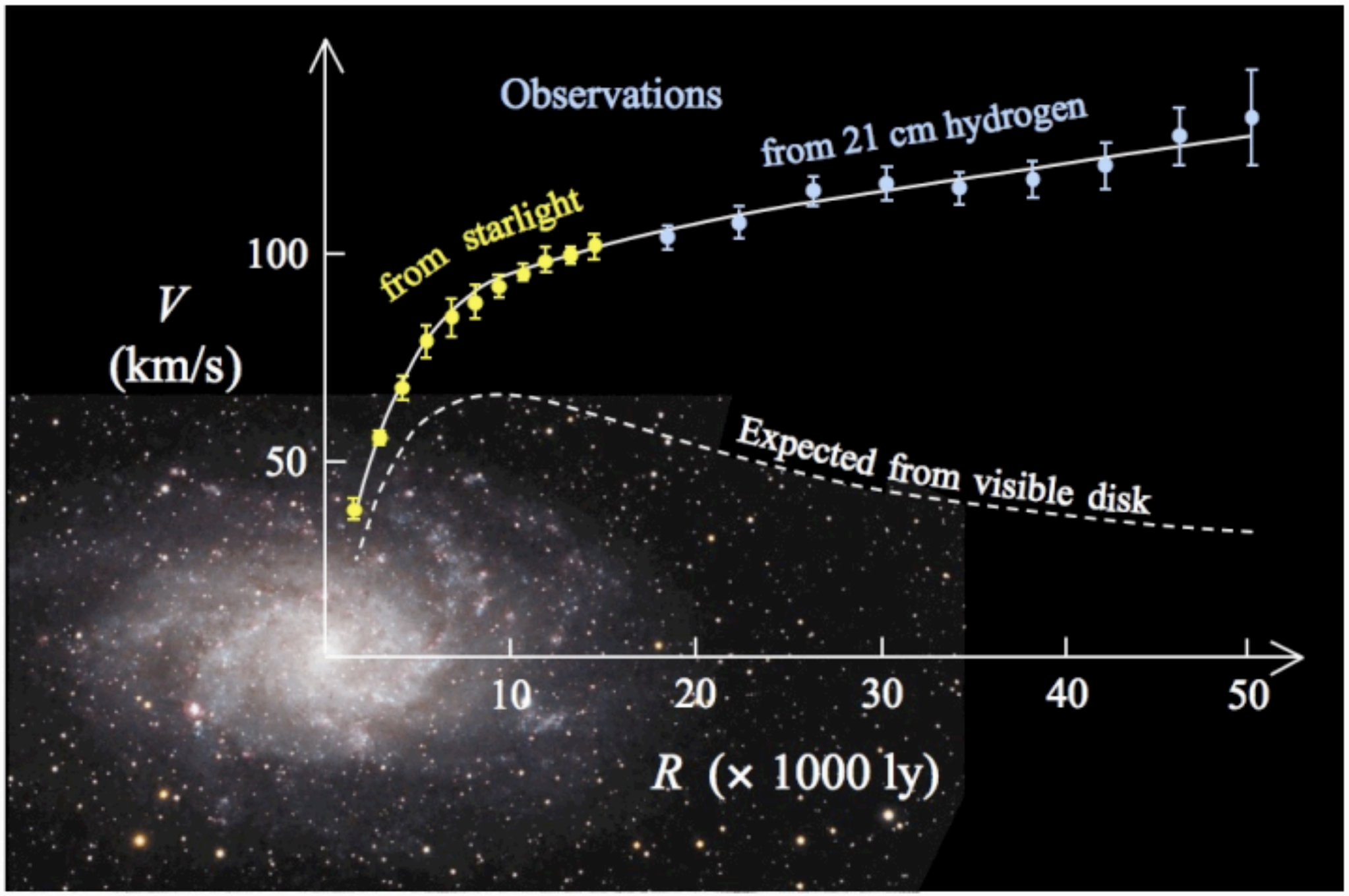
We haven't found Dark Matter either

Let me elaborate on that...

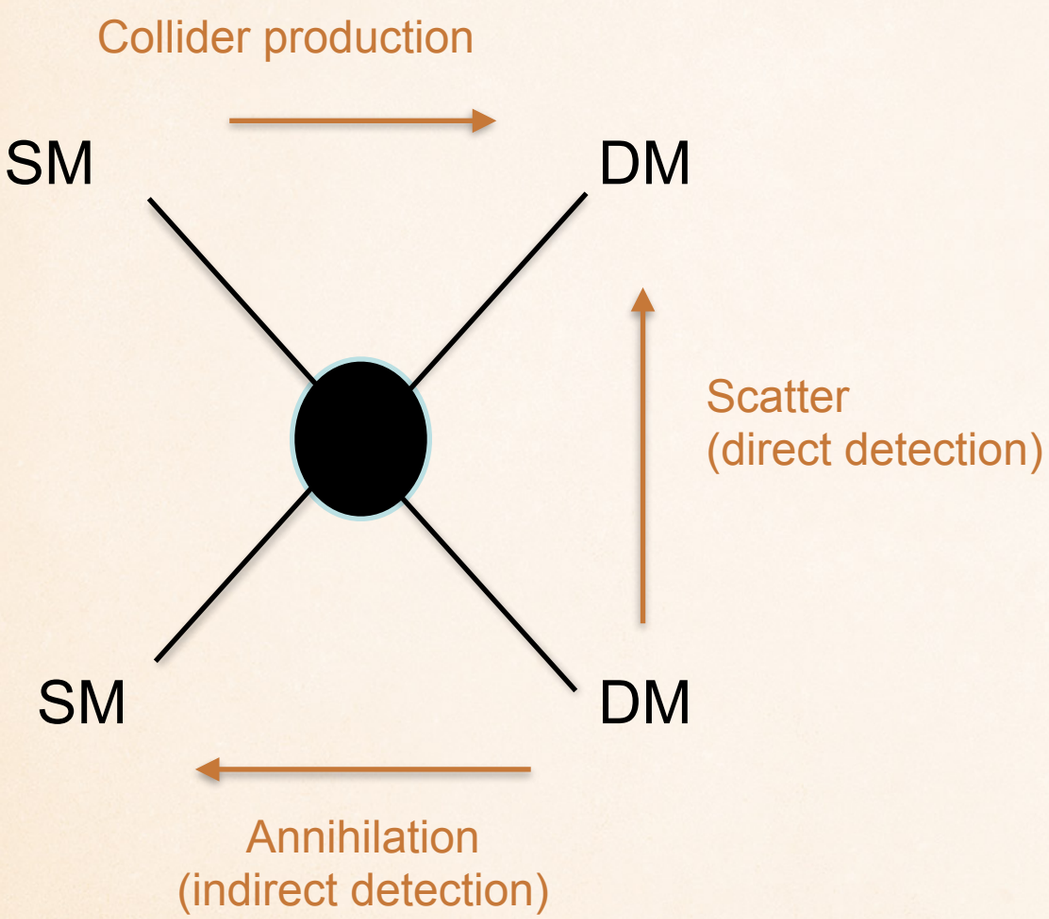
The Standard Model describes very well measurements at colliders...



Nevertheless, we know something else is out there



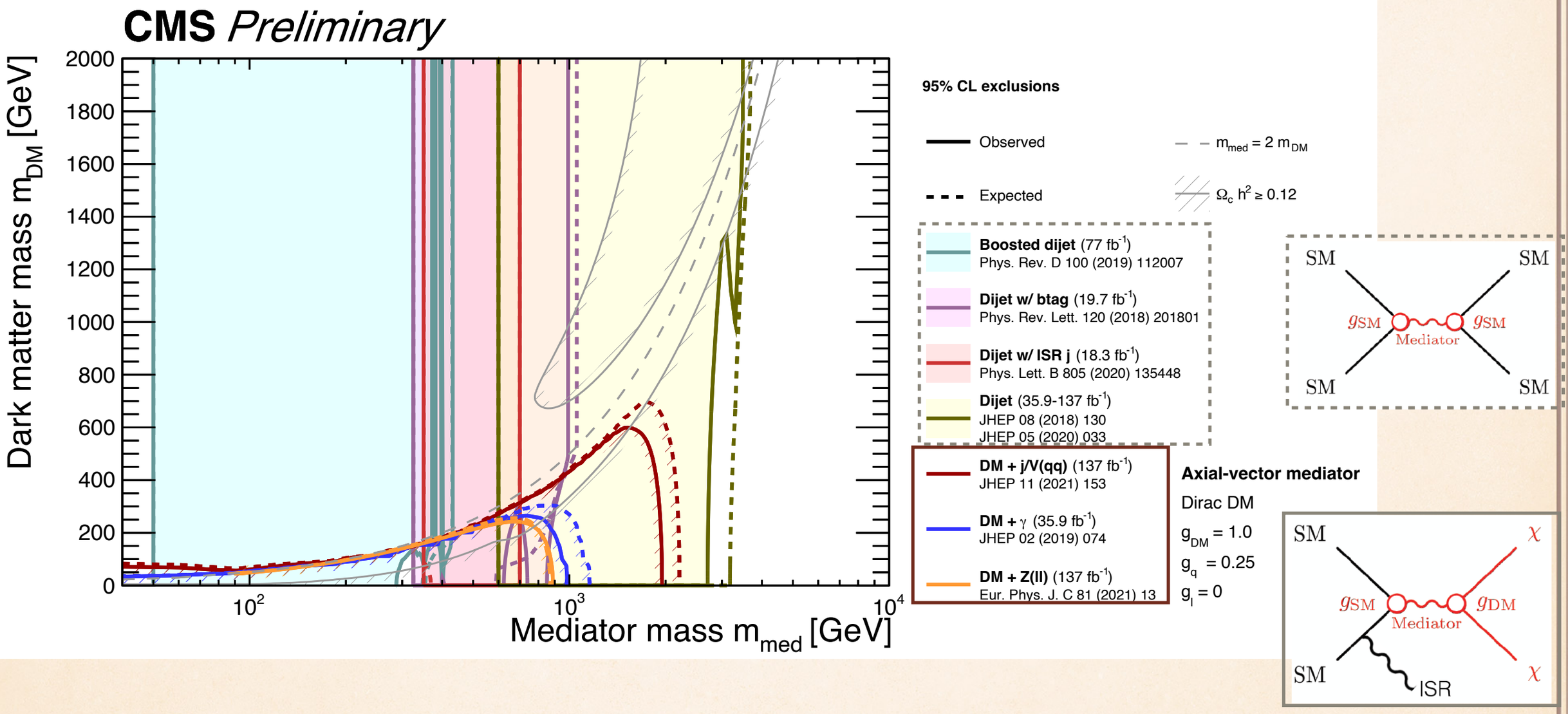
is it something that can be produced at colliders ?



we don't know - but we should pursue all avenues to discover the nature of Dark Matter

S-CHANNEL SPIN 1 MEDIATOR

CMS DM summary plots

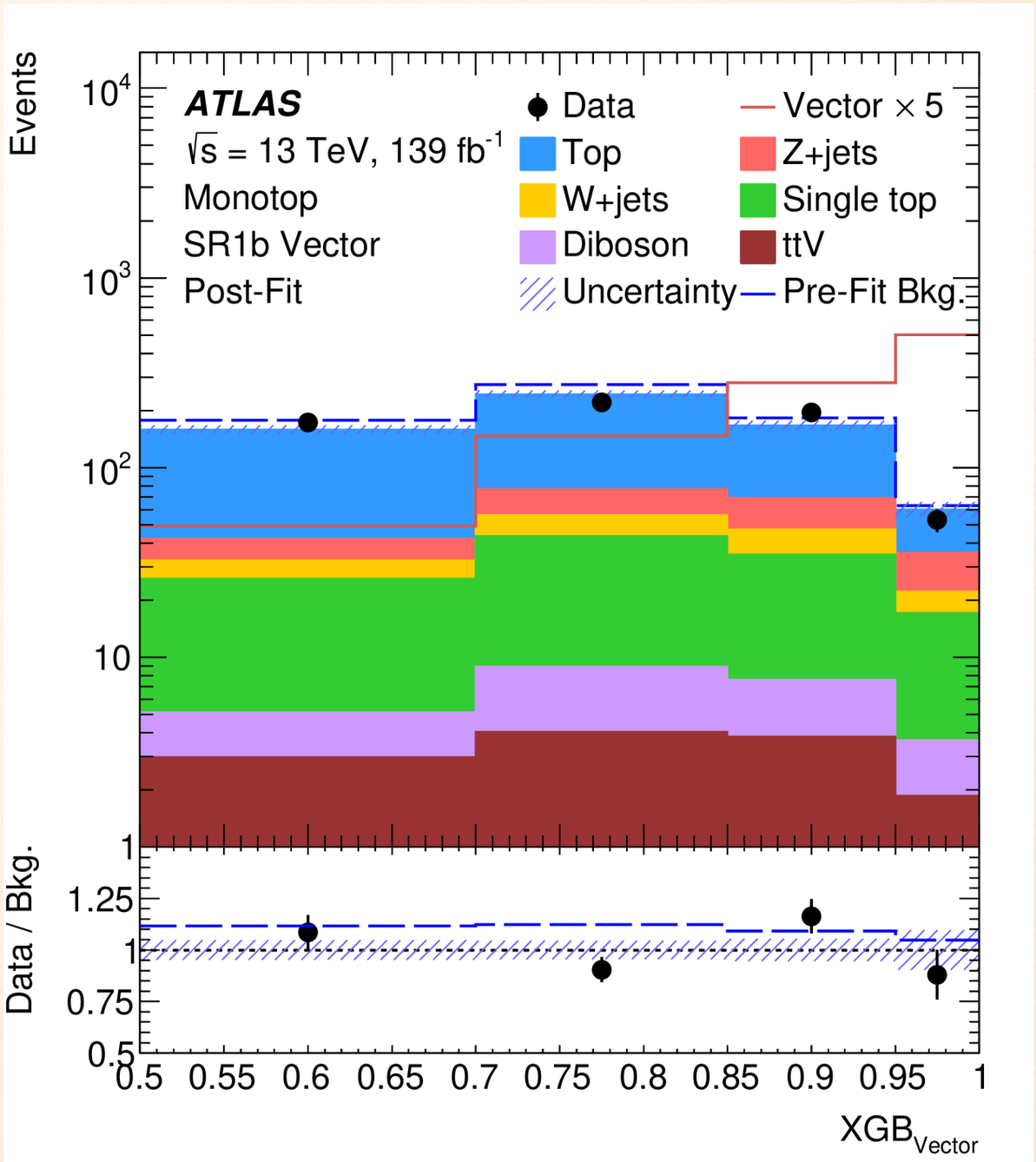


ATLAS corresponding plot in backup and here

arXiv:2402.16561

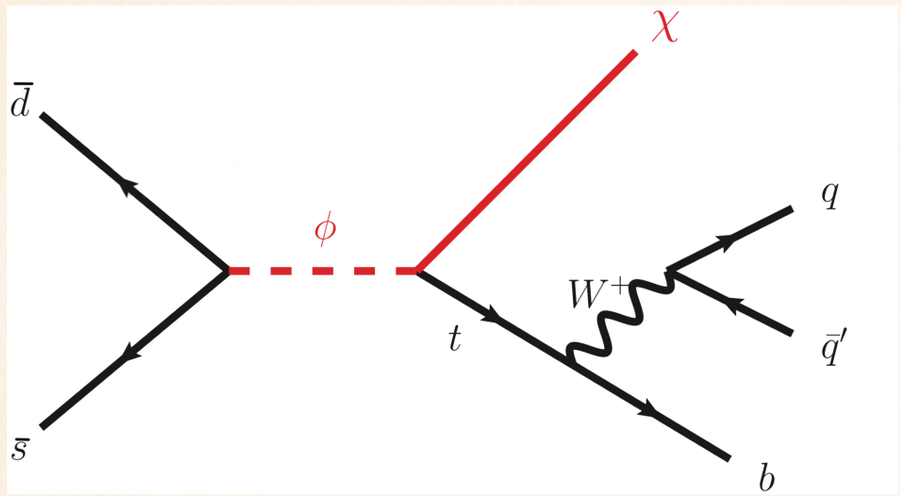
ATLAS MONO-TOP

- Targets vector and scalar mediators coupling to Dark Matter
- Selection : top tagged large-R jet, large missing momentum E_T^{Miss}. BDT separates signal and background
- Background MC normalized in Control Regions

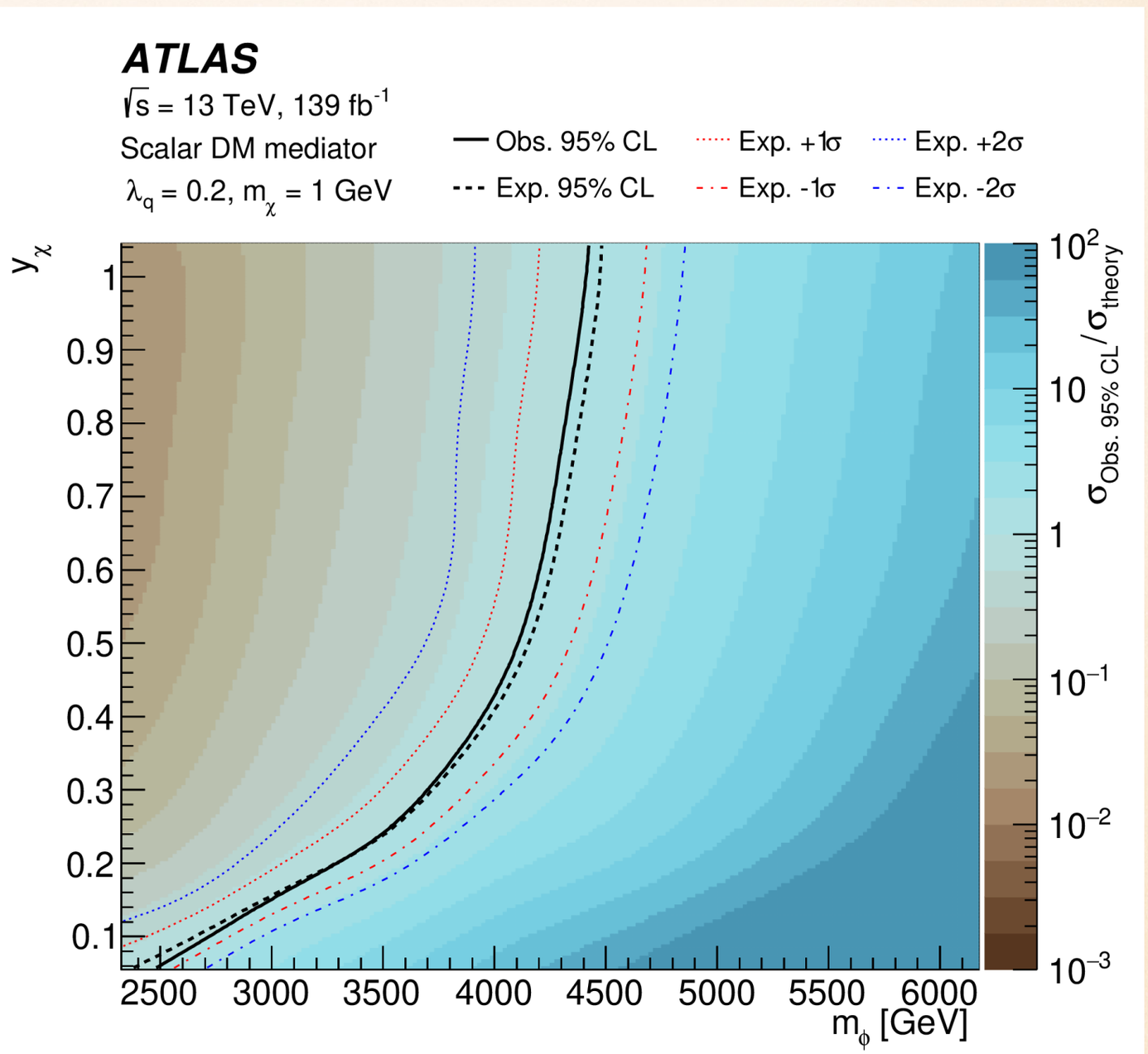


arXiv:2402.16561

ATLAS MONO-TOP



- 2 models with 4 parameters (mediator and DM masses, quark and DM couplings)
- Limits in various 2D projections

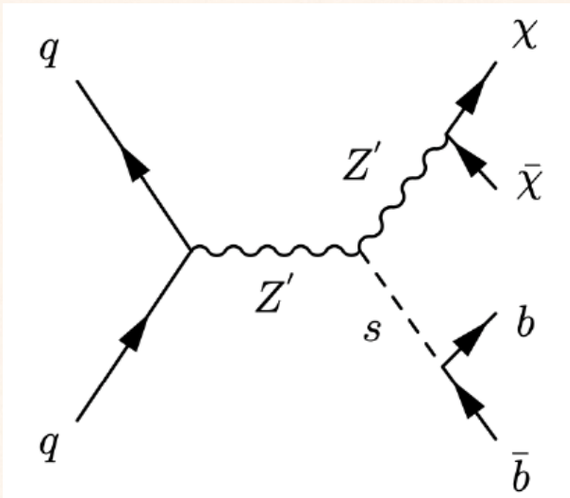


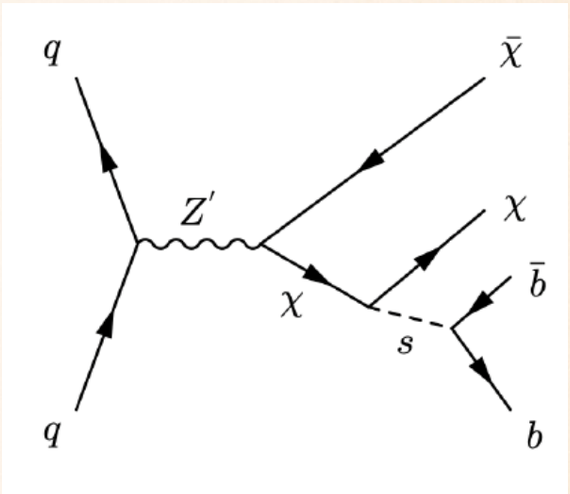
New!

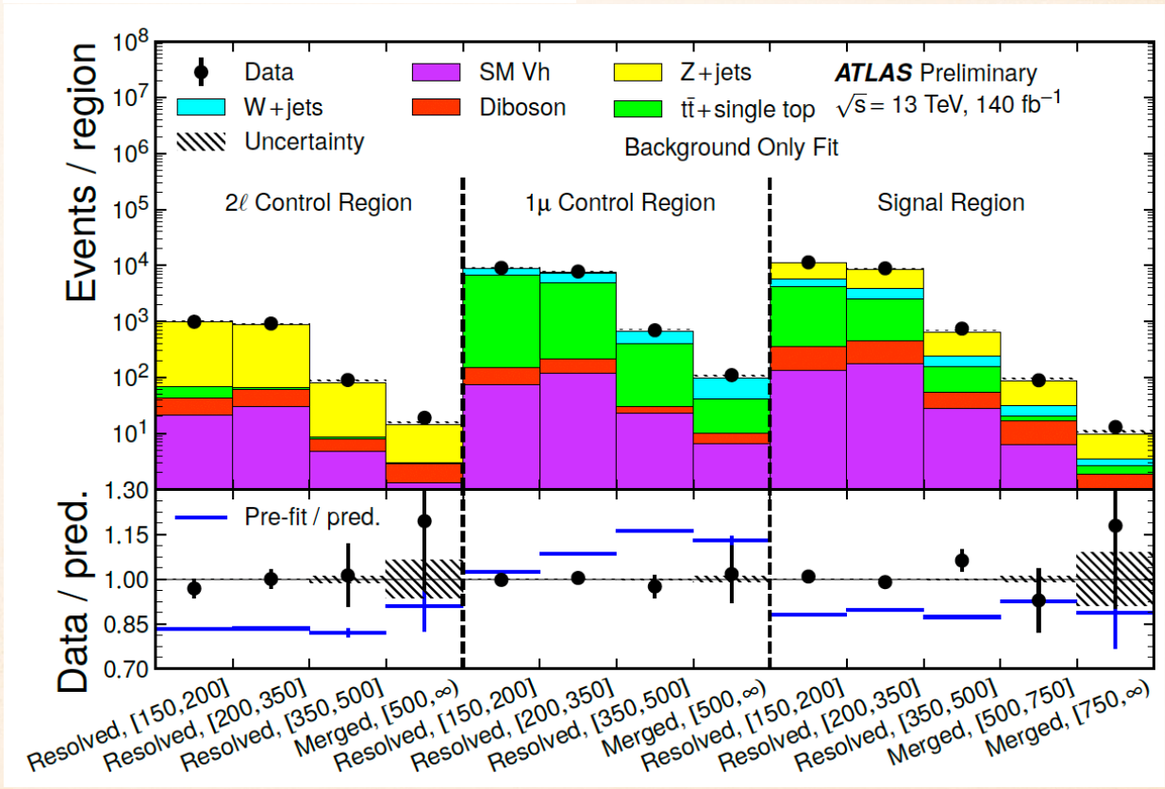
ATLAS-CONF-2024-004

ATLAS DARK HIGGS IN BB

- Model with Dark Higgs, mediator, DM particle
- E_T^{Miss} + bb resonance, first search for m_{bb}<150 GeV and not from SM h.
- Large R jet with novel dedicated Xbb tagging (gives access to low masses) or 2 resolved b jets
- Backgrounds normalized in 1L, 2L CRs



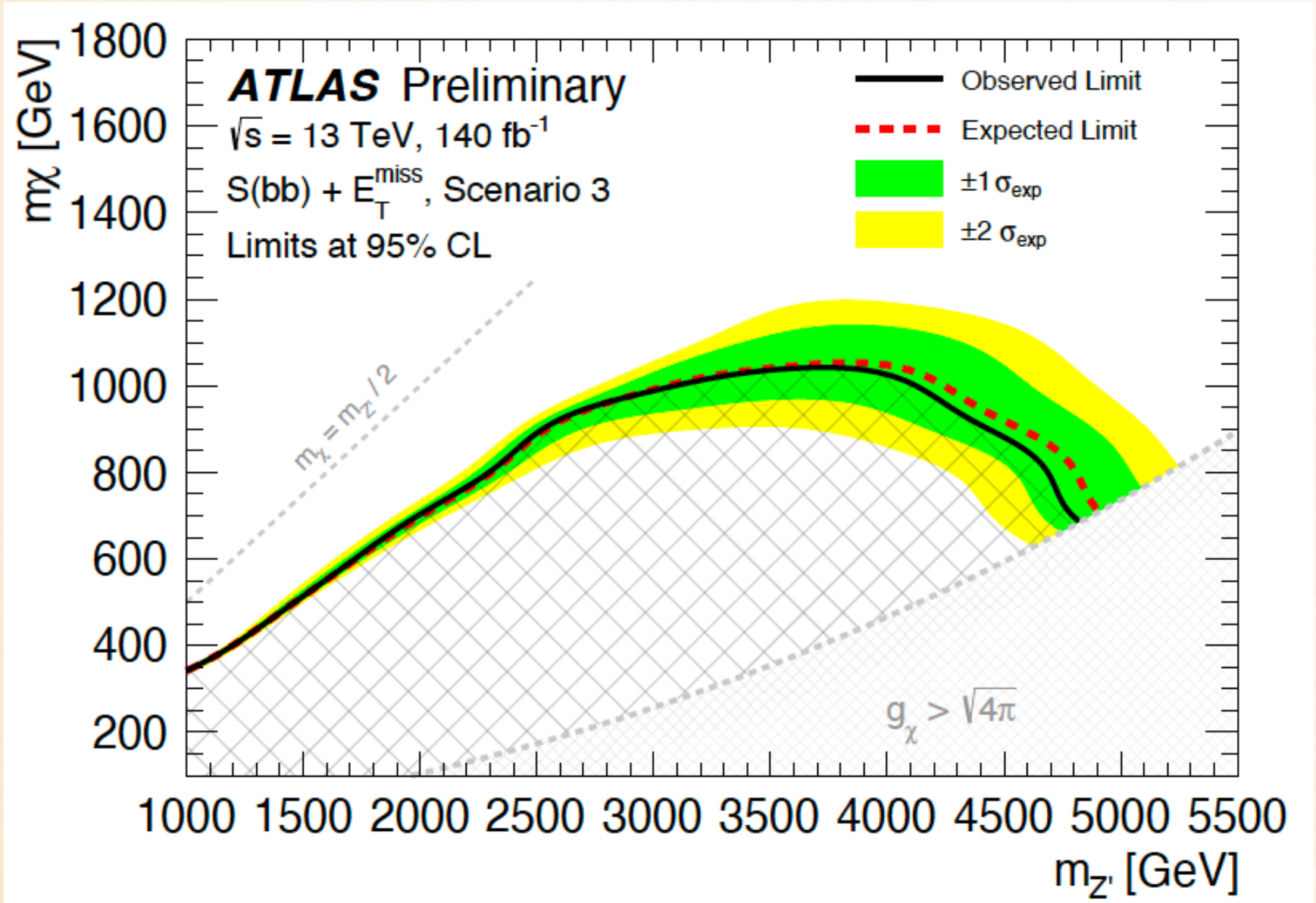




New!

ATLAS-CONF-2024-004

ATLAS DARK HIGGS IN BB



m_S = 70 GeV

g_q = 0.25

sin theta = 0.01

g_χ varied to match relic density

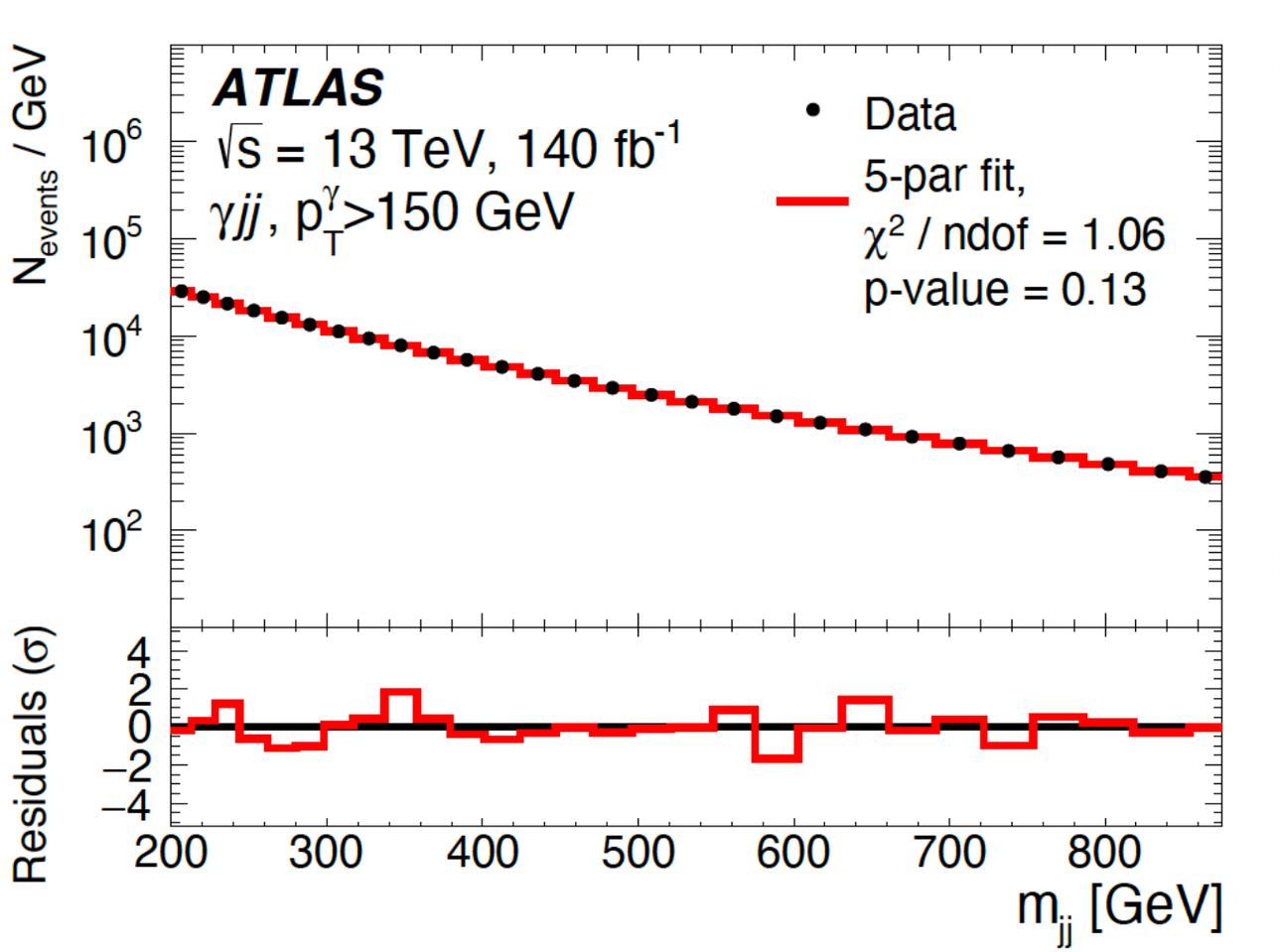
Limits in various 2D slices of parameter space

New!

arXiv:2403.08547

ATLAS LOW MASS DI-JETS

- Using an ISR jet or photon to trigger and access lower mass mediators
- Resonance in inclusive or b-tagged resolved jets : four channels (γjj, γbb, jjj, jbb)
- Fit smoothly falling m_{jj} spectrum

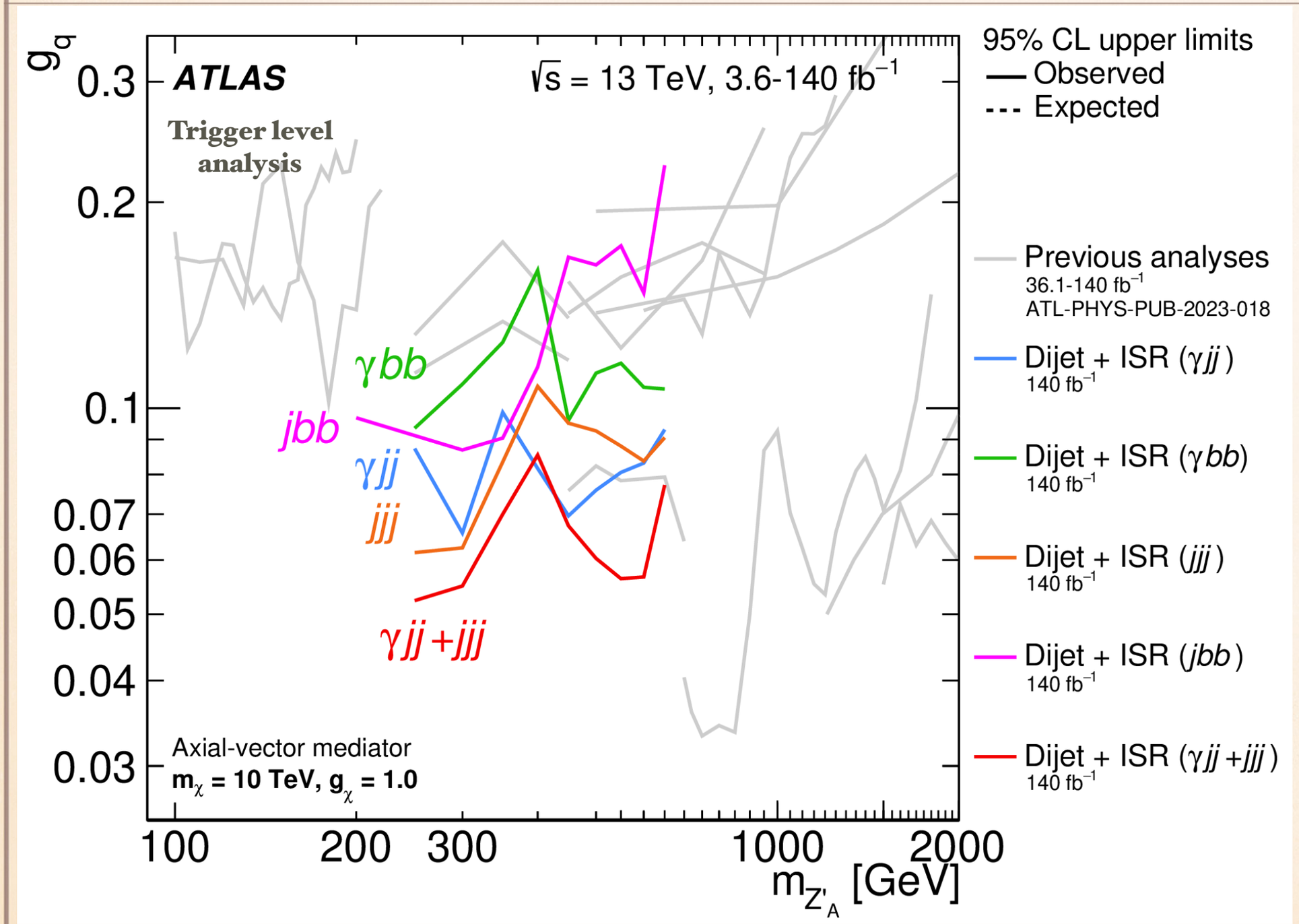


See here for the CMS jet resonance search with data scouting

New!

arXiv:2403.08547

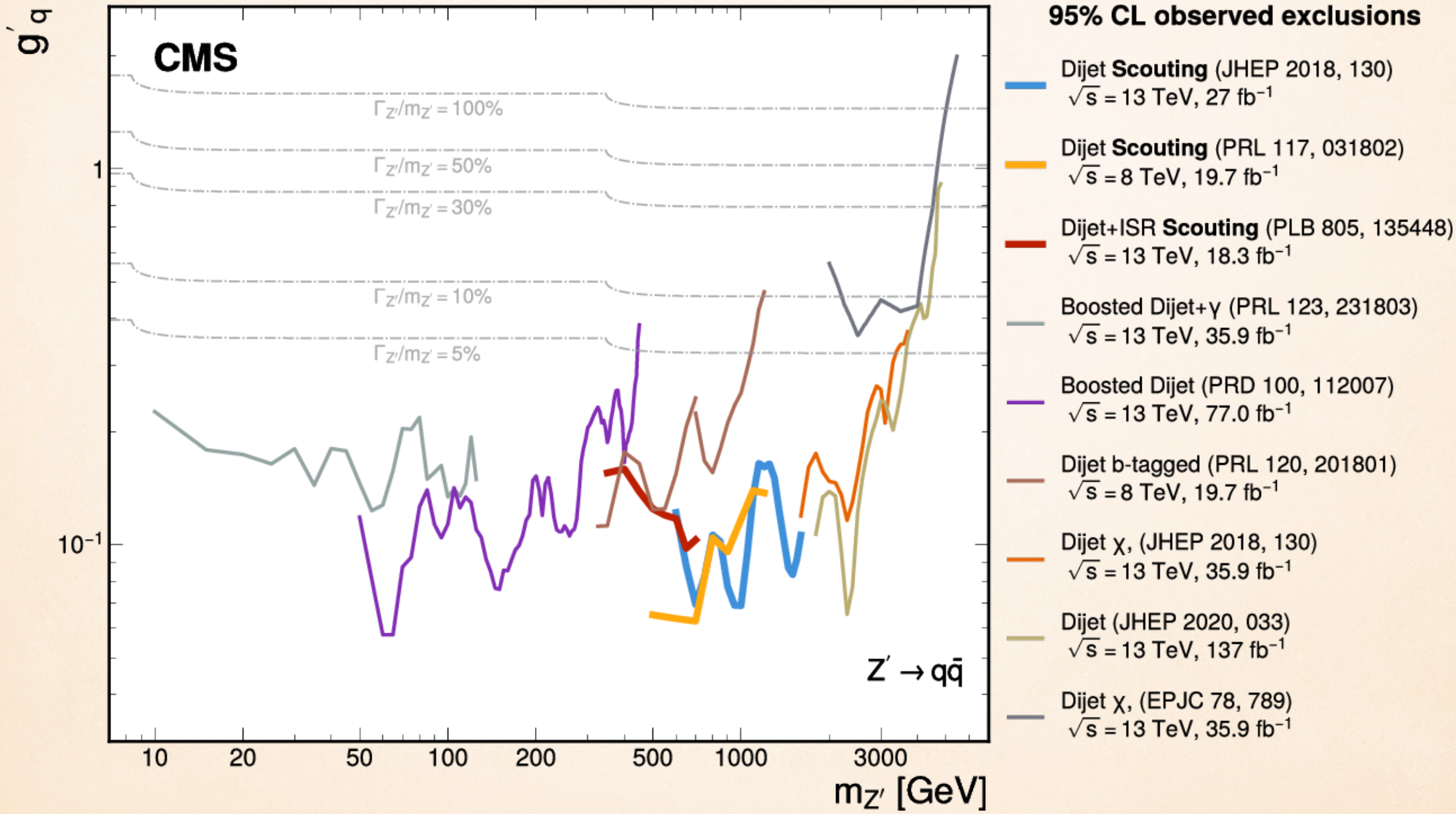
ATLAS LOW MASS DI-JETS



New!

CMS-EXO-23-007

CMS DI-JETS SUMMARY



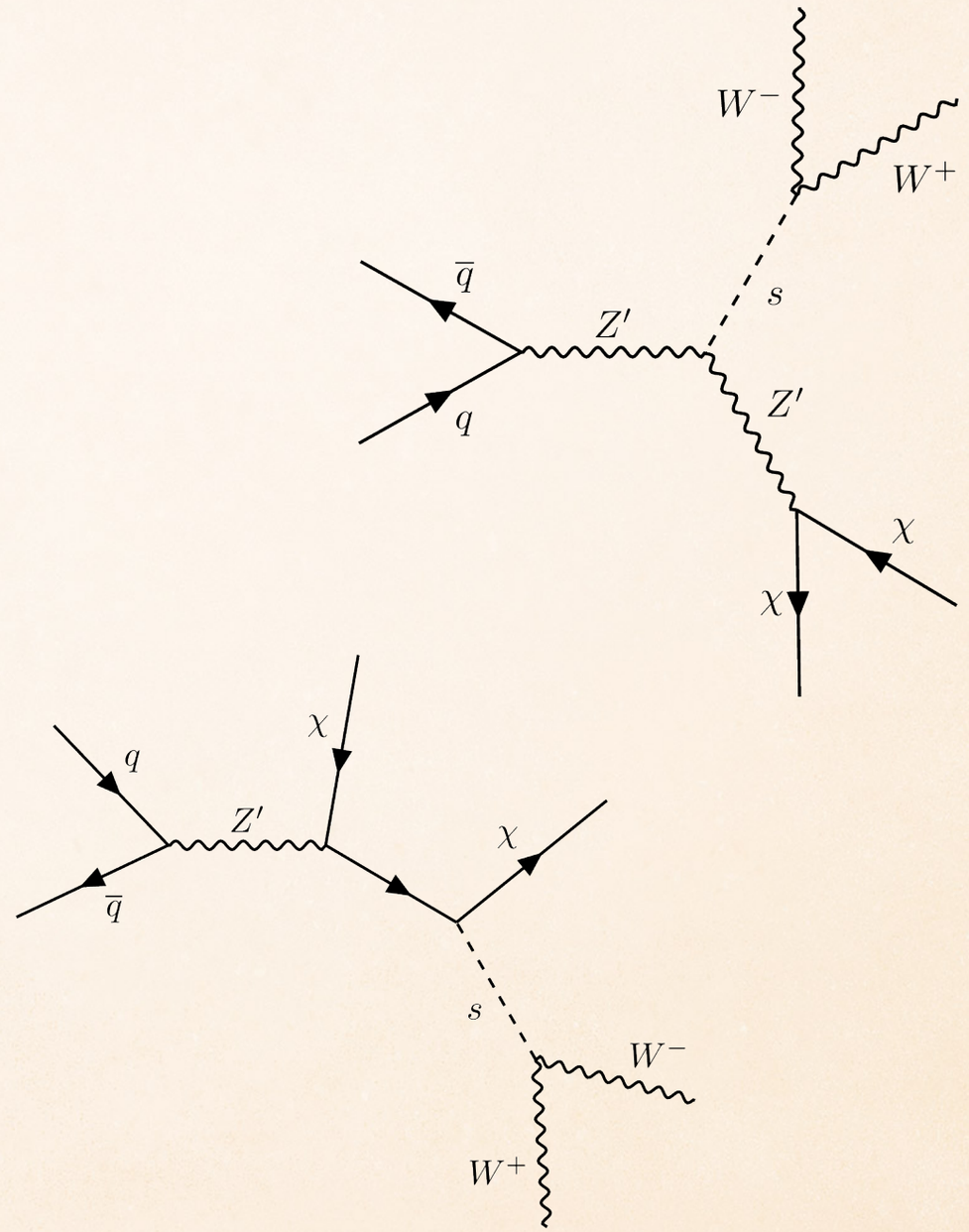
arXiv:2310.12229

CMS DARK HIGGS IN WW

- Target : Dark Sector with Z', Dark Higgs, and Dark Matter

- WW+MET in lνqq and 2l channels

- Prompt lepton background from MC, normalized in region inverting the SR cuts



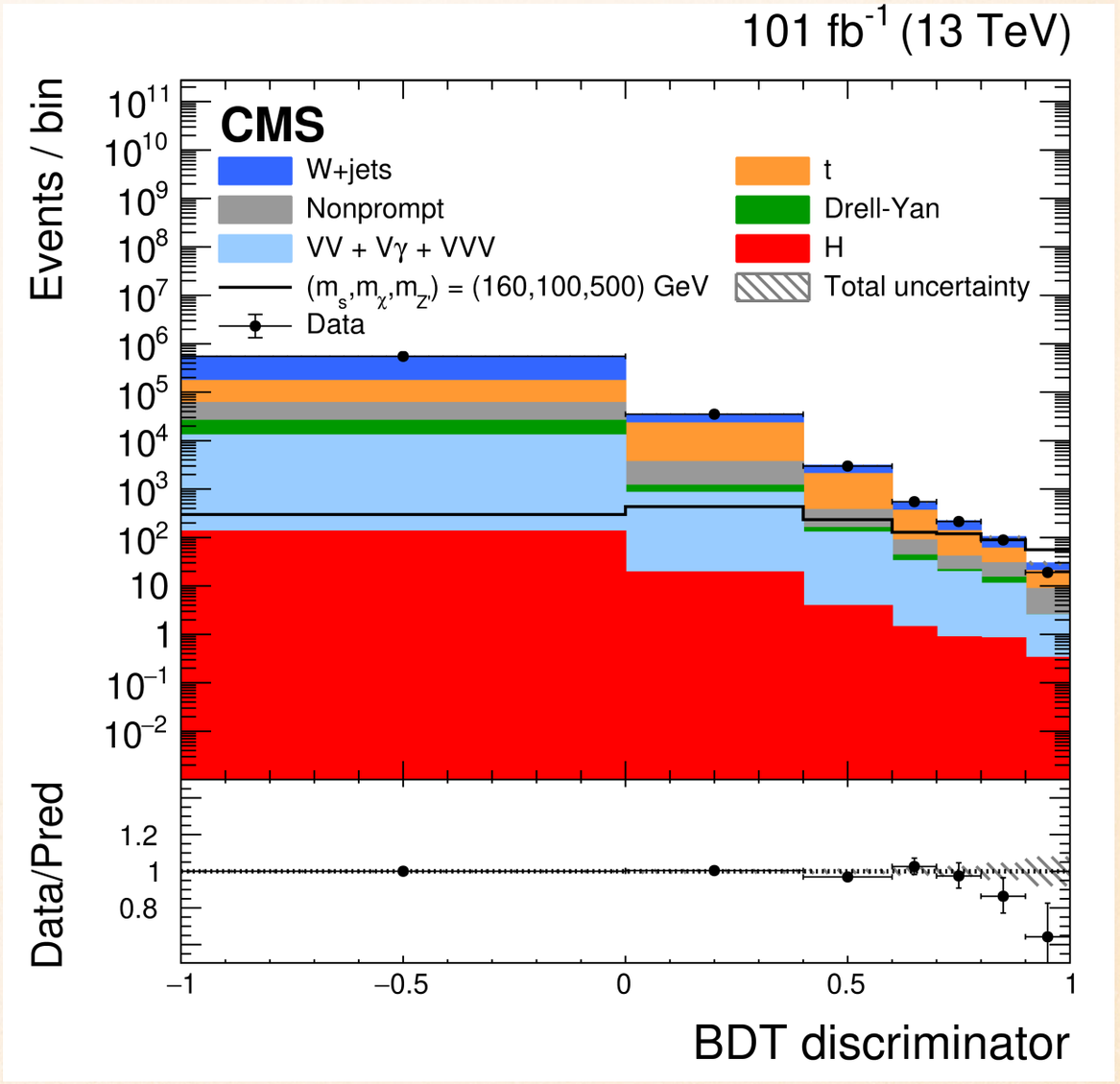
arXiv:2310.12229

CMS DARK HIGGS IN WW

- Target : Dark Sector with Z', Dark Higgs, and Dark Matter

- WW+ E_T^{Miss} in lνqq and 2l channels

- Prompt lepton background from MC, normalized in region inverting the SR cuts

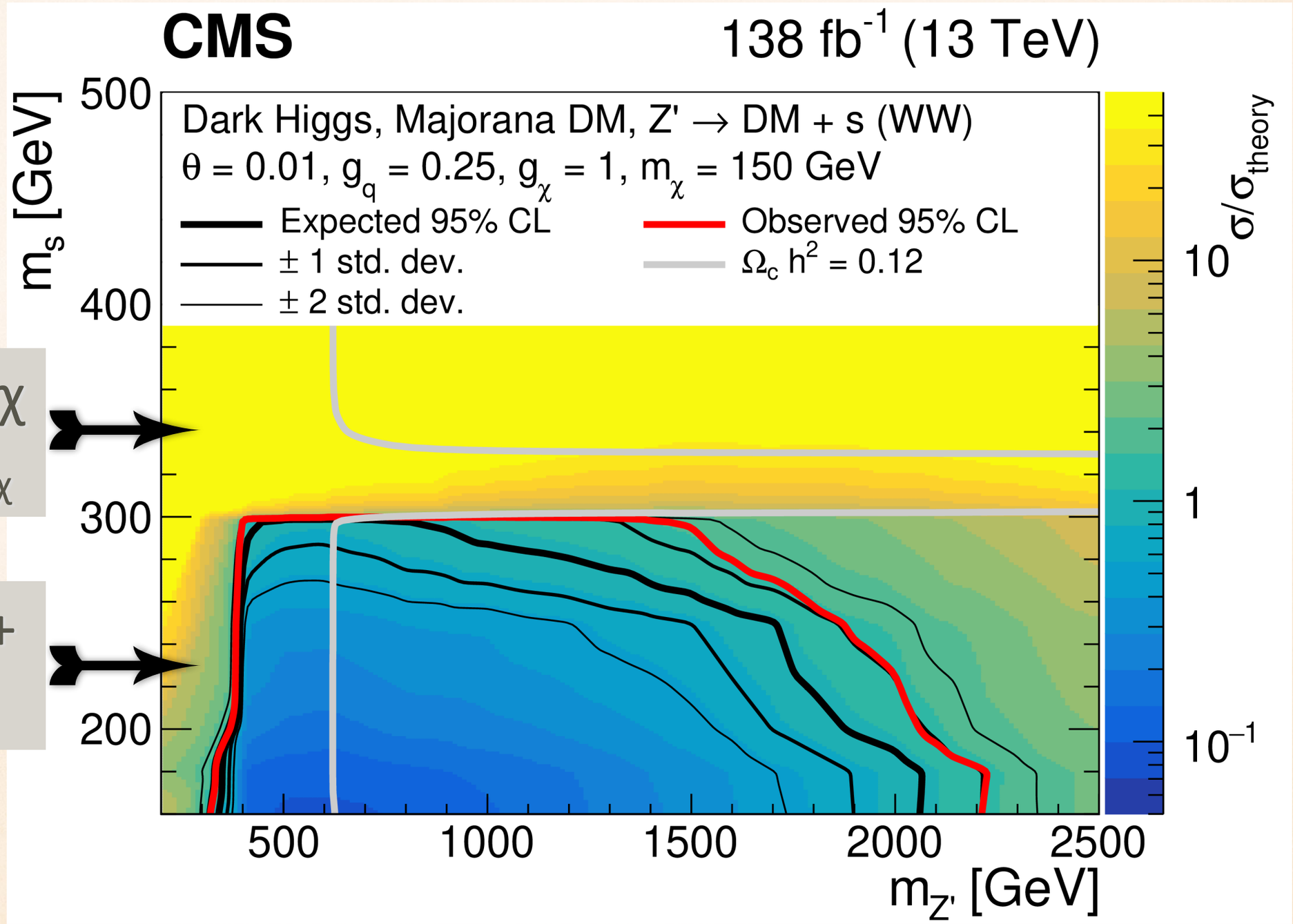


arXiv:2310.12229

CMS DARK HIGGS IN WW

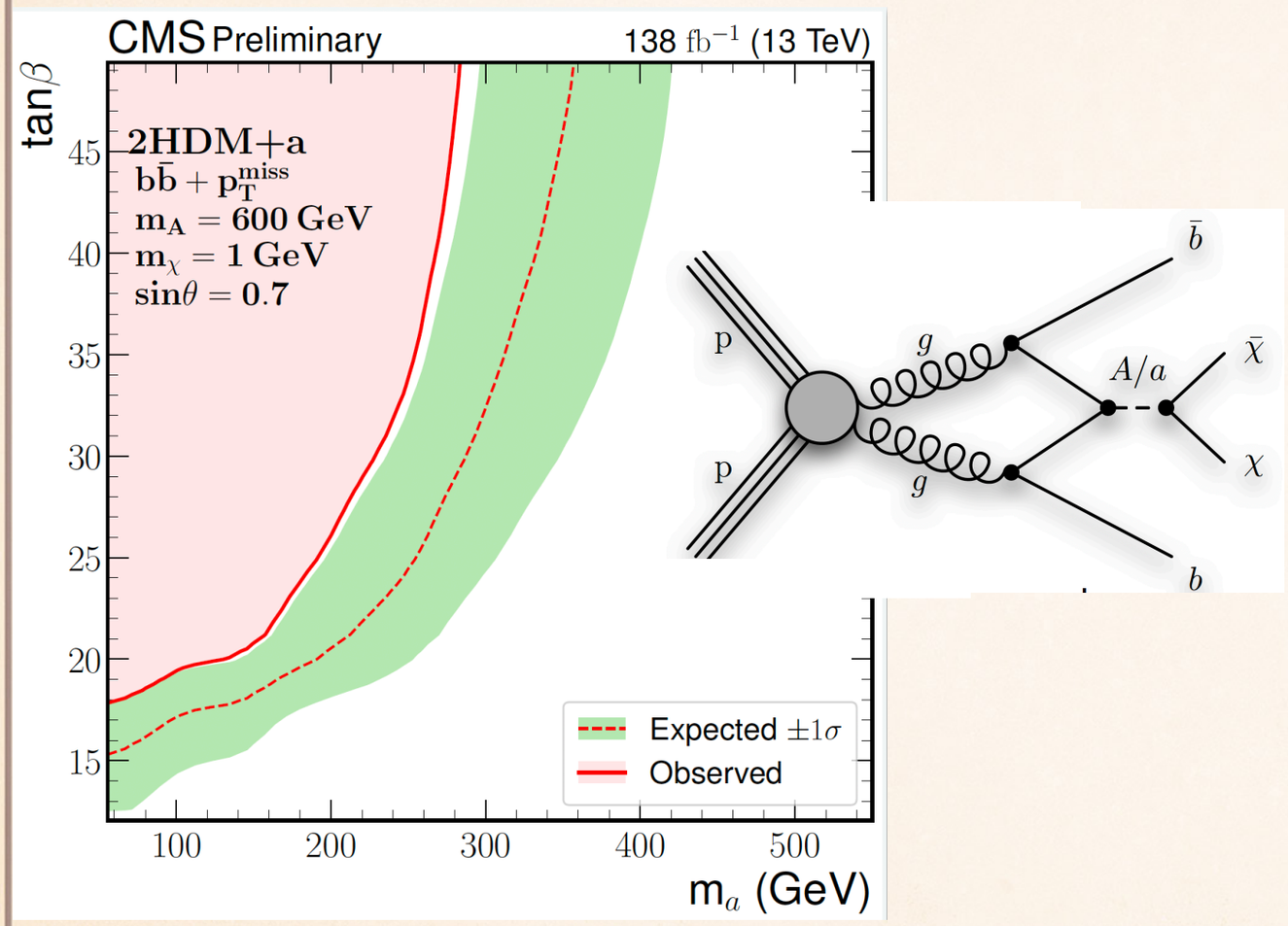
s decays to χχ for $m_s > 2\ m_\chi$

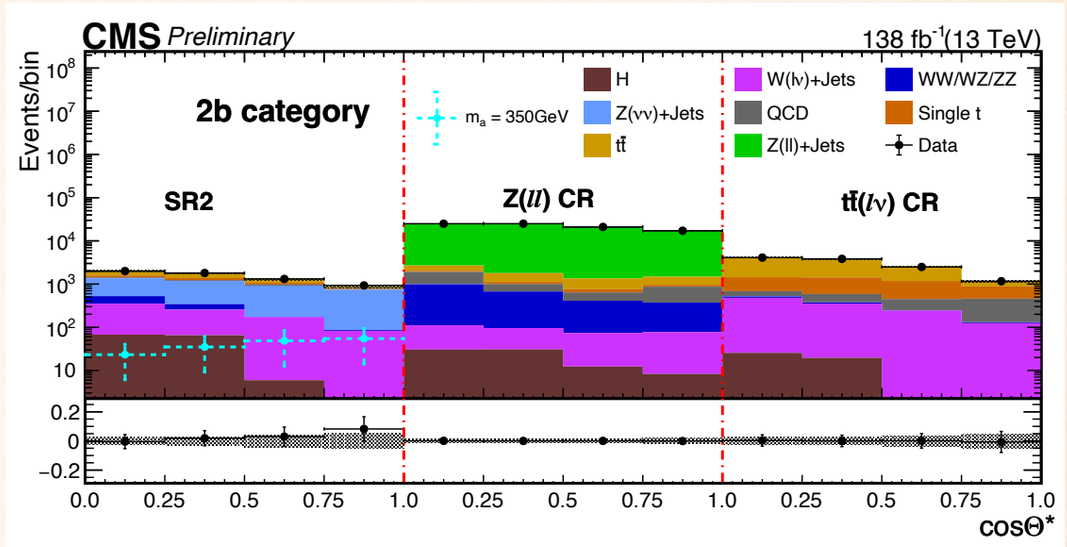
$mZ' < 2m_W + 2m_\chi$

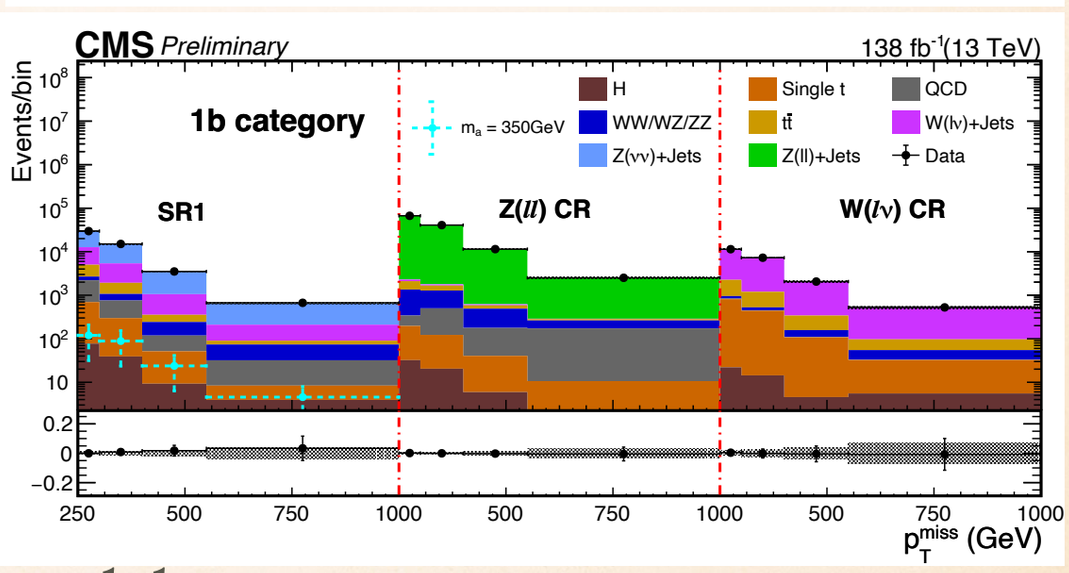


New!

CMS NEW RESULT !

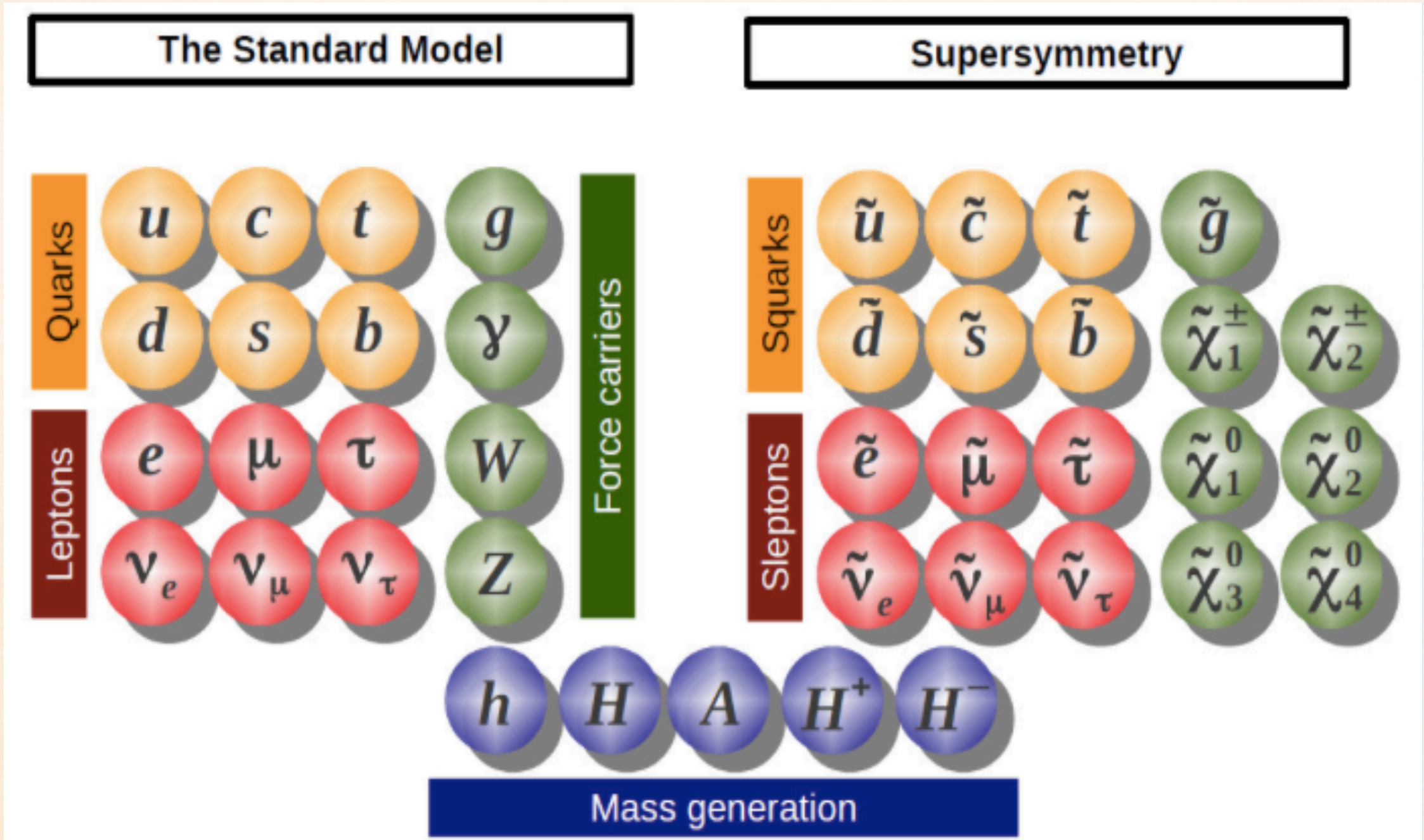




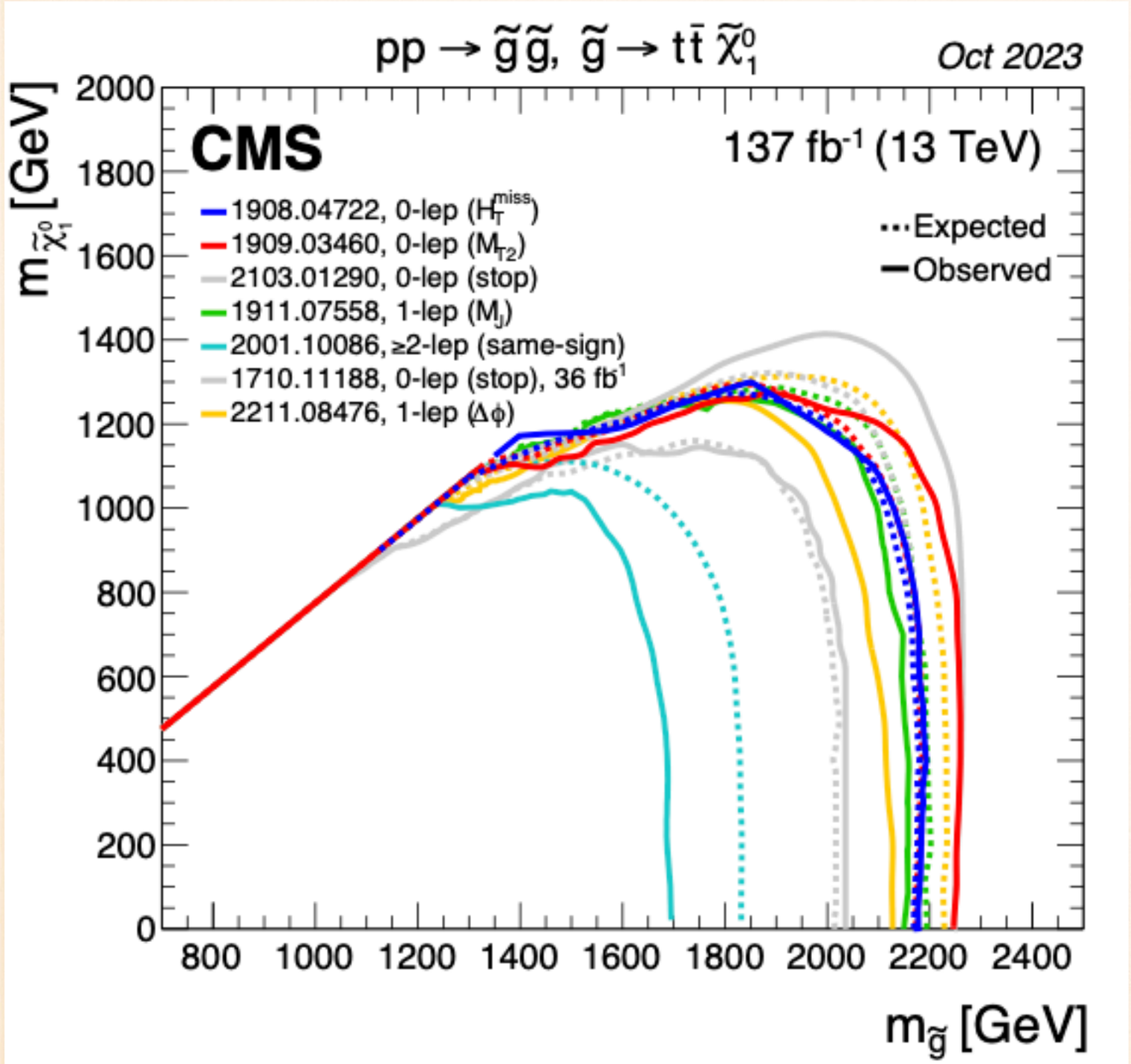


- New bb+p_T^{miss} search, targeting 2HDM+a model
- Dedicated talk of Praveen Tiwari in today's YSF session

SUPERSYMMETRY



STRONG PRODUCTION

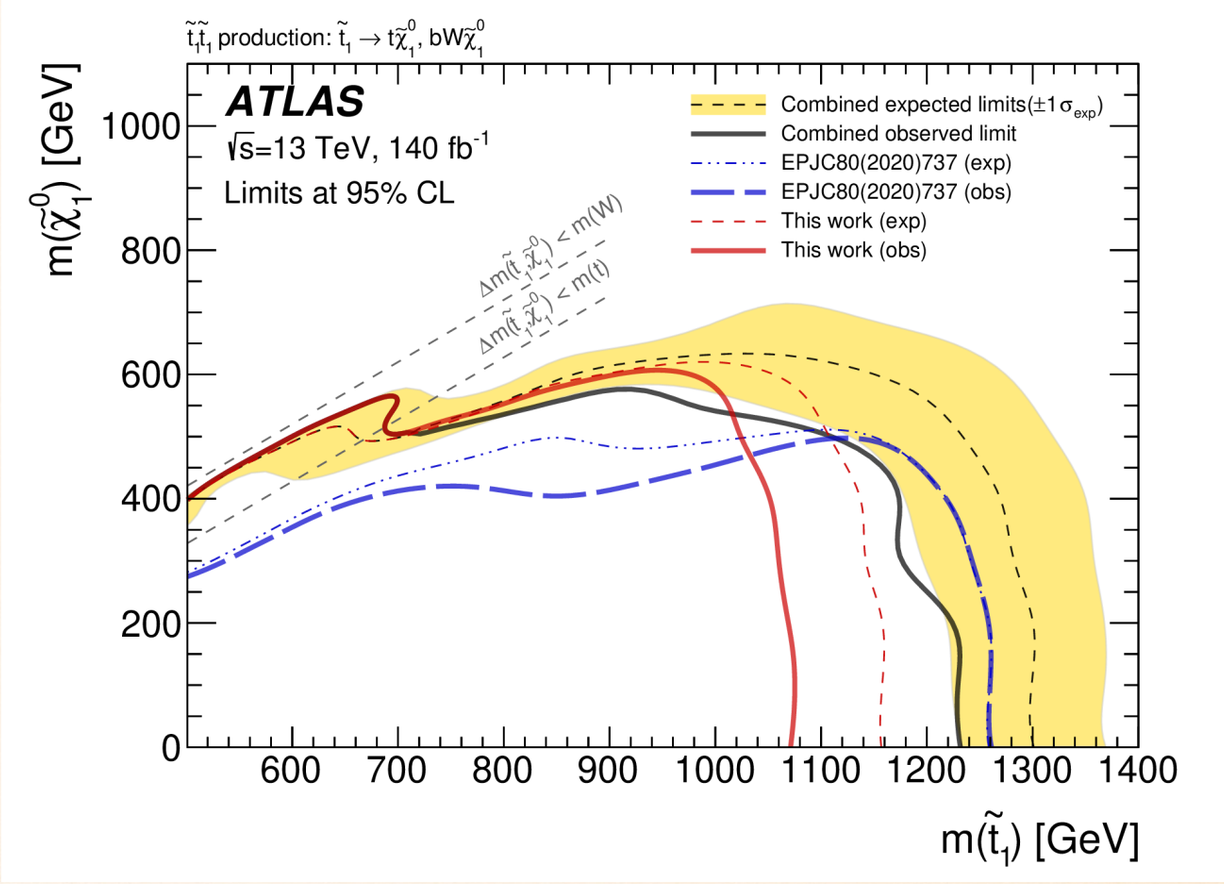


- Strong limits on gluino and squark production
- Focus is shifting to difficult/unusual models, advanced analysis techniques, and combinations

arXiv:2401.13430

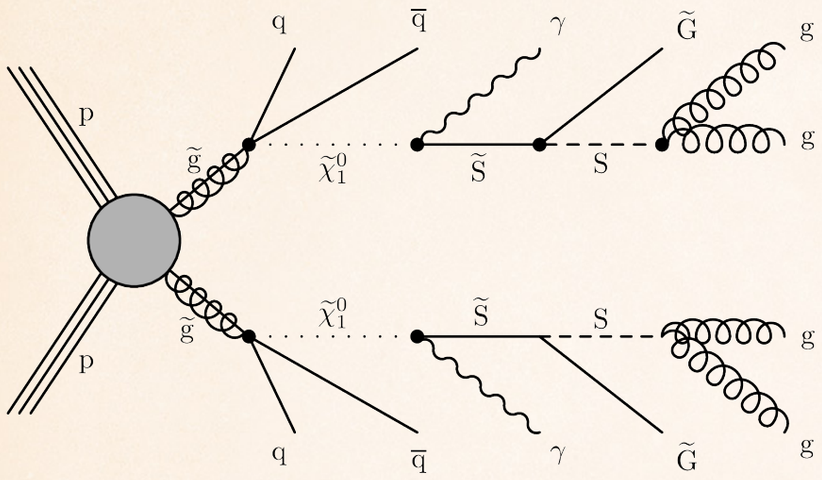
ATLAS STOP 1L

- 2nd ATLAS paper with full run 2 dataset targeting stop pair production in 1 lepton channel
- Neural Networks to reconstruct top hadronic decays and S/B separation
- Optimization for smaller $\Delta m(\tilde{t},\tilde{\chi})$
- Combination with 0L channel

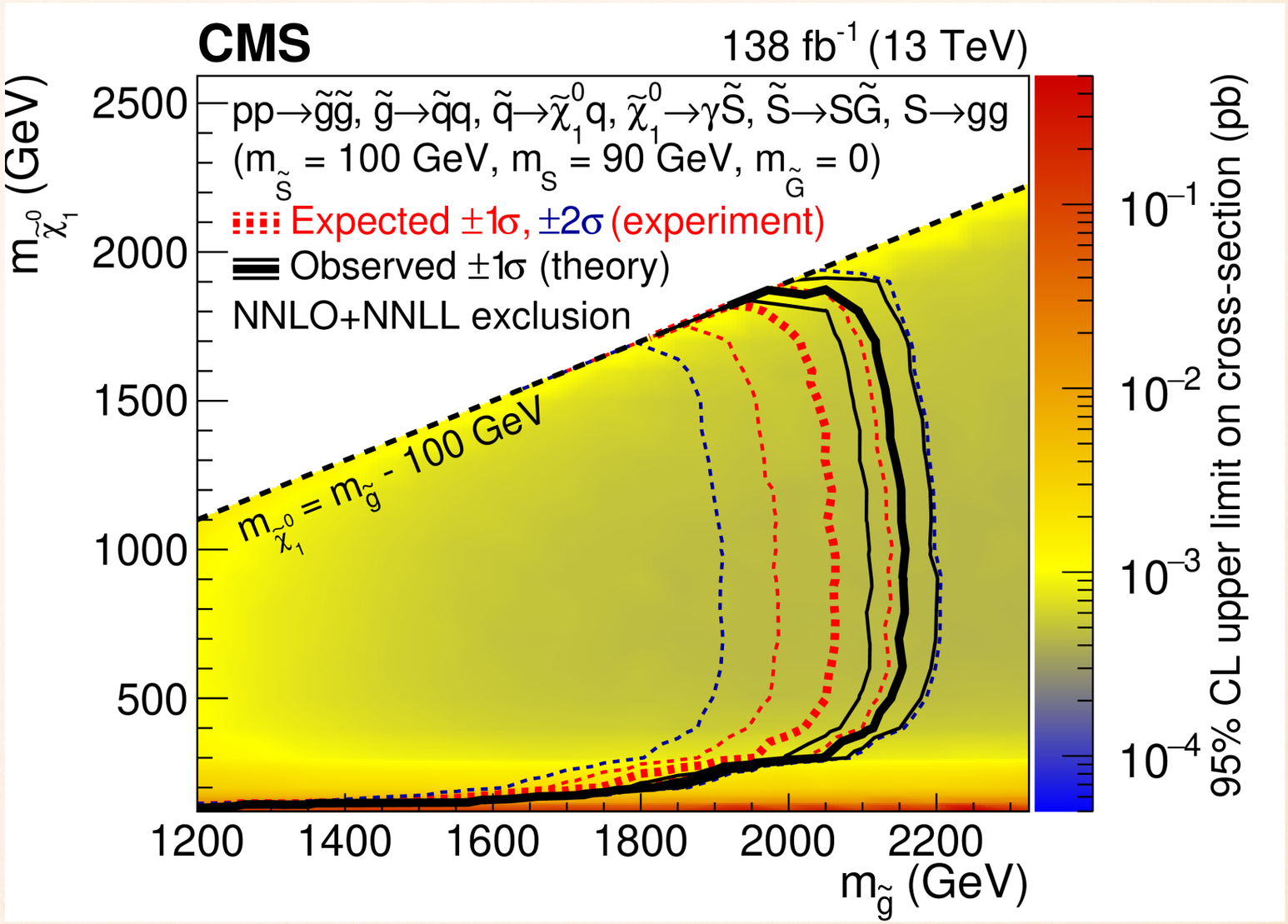


arXiv:2310.03154

CMS STEALTH SUSY



Hidden sector with nearly degenerate singlet S and singlino S, decay has little p_T^{miss}



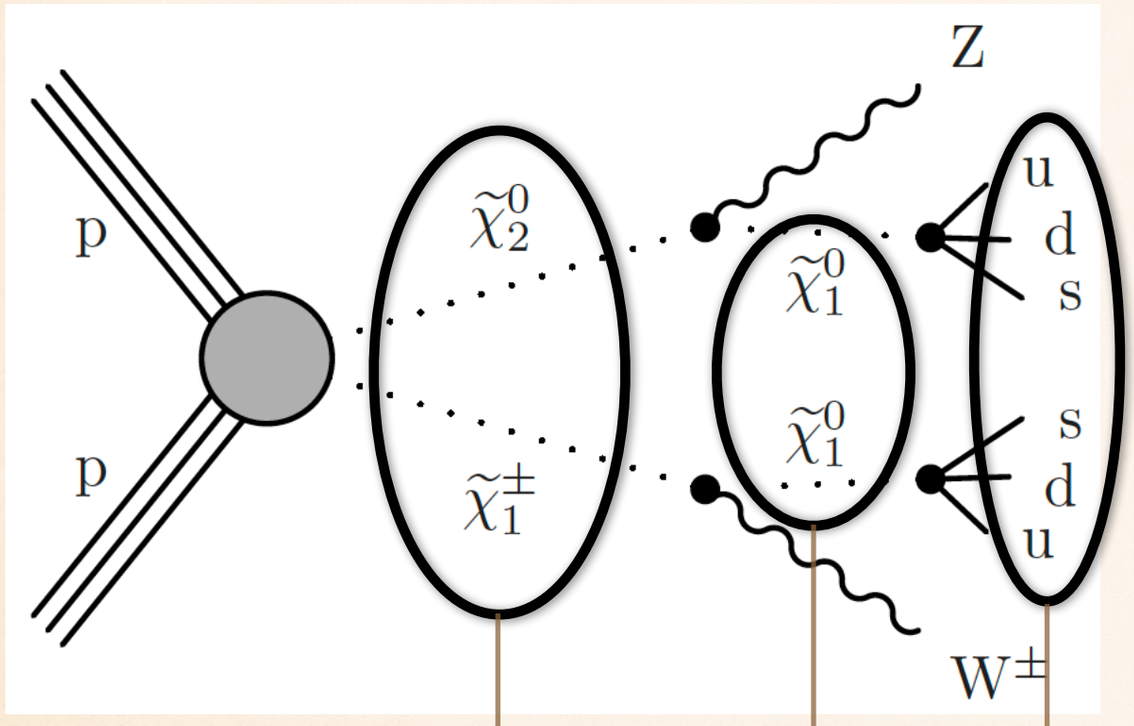
Limits on gluino and squark

New!

PAS-SUS-23-015

CMS NEW RPV RESULT

Target :



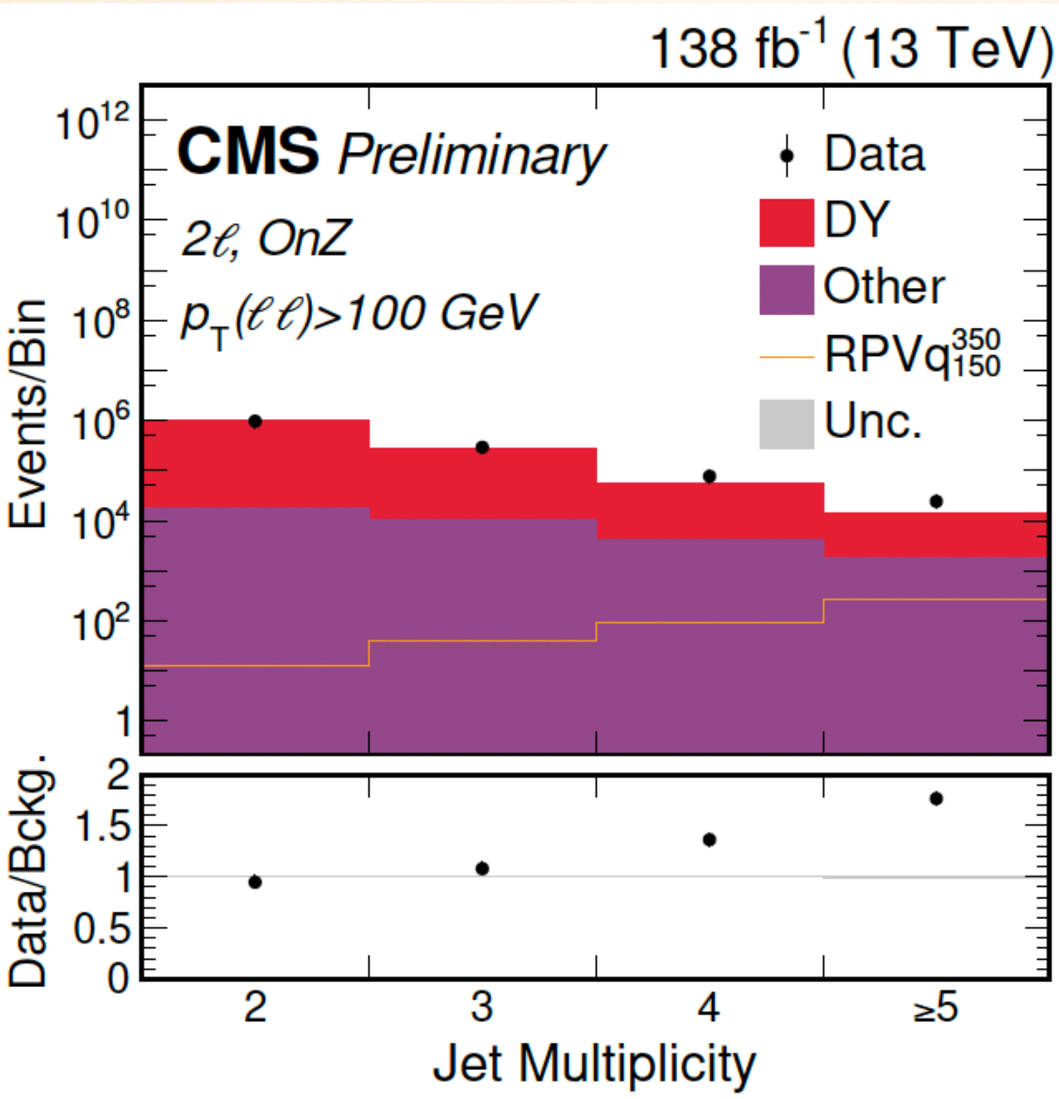
Signature :

- 3 leptons from W,Z decays
- 2,3,4,5+ jets with/wo b-tagged jets (8 channels)
- Large S_T (sum of scalar momenta)

New!

PAS-SUS-23-015

CMS NEW RPV RESULT



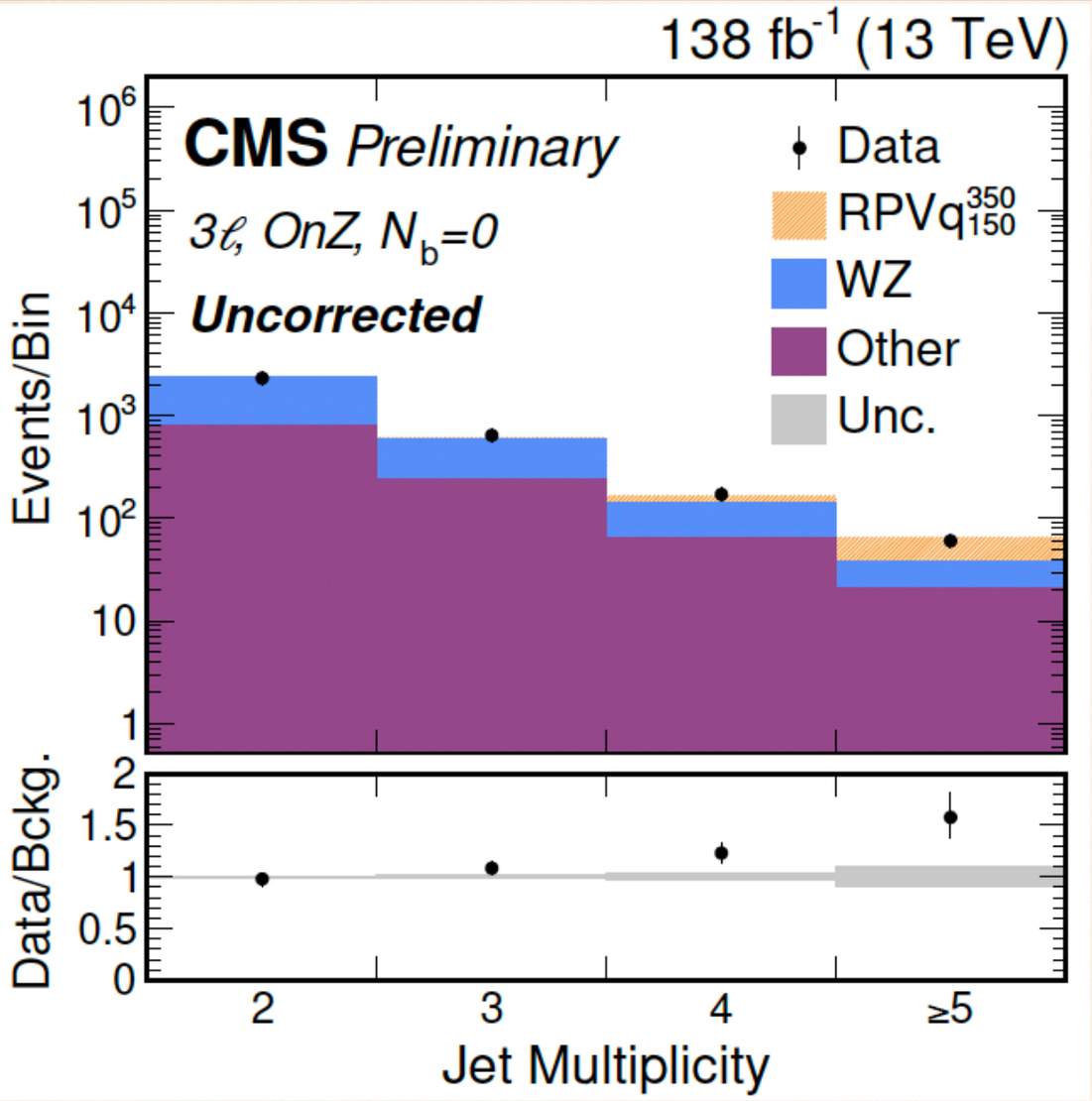
Background MC (WZ+jets, ttZ+jets) corrected with jet scaling factors measured in data

Measure jet scaling in Z+jets events

New!

PAS-SUS-23-015

CMS NEW RPV RESULT



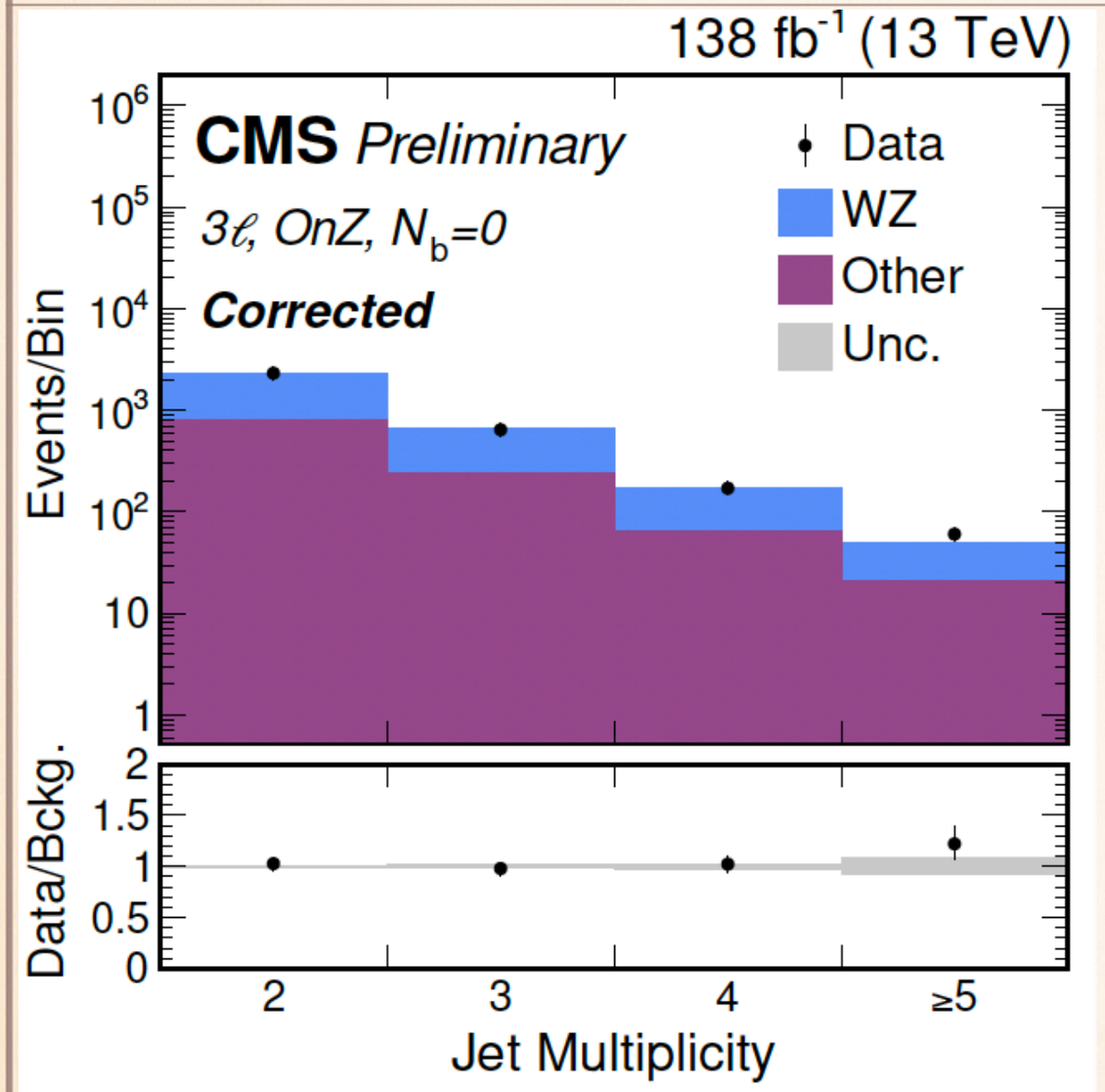
Background MC (WZ+jets, ttZ+jets) corrected with jet scaling factors measured in data

3 lepton selection wo corrections, showing excess

New!

PAS-SUS-23-015

CMS NEW RPV RESULT



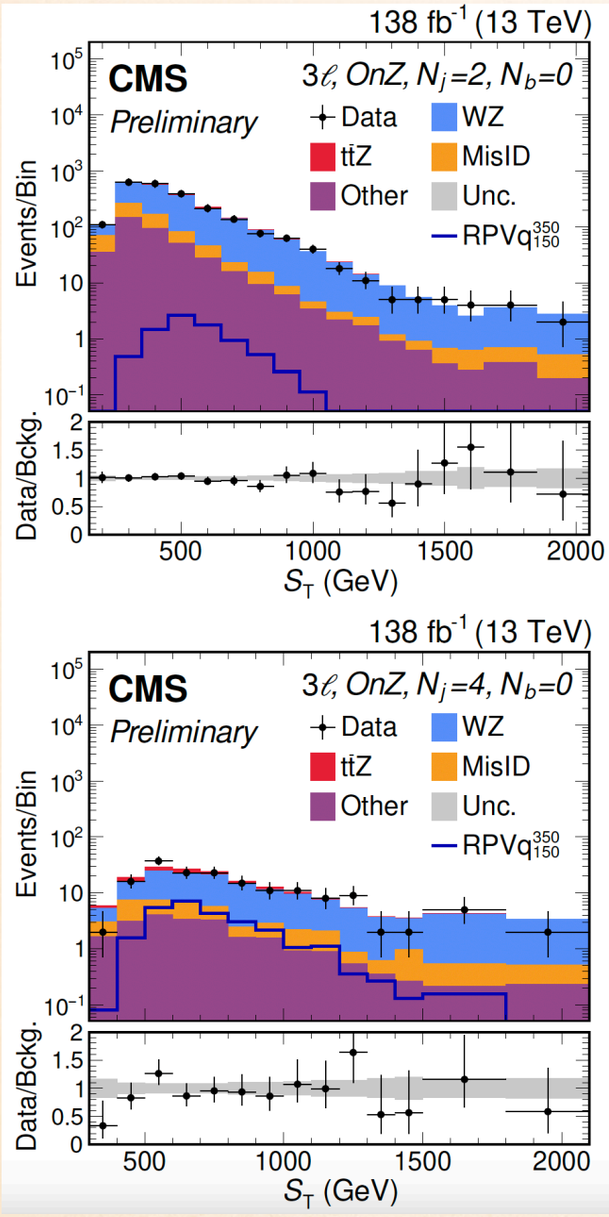
Background MC (WZ+jets, ttZ+jets) corrected with jet scaling factors measured in data

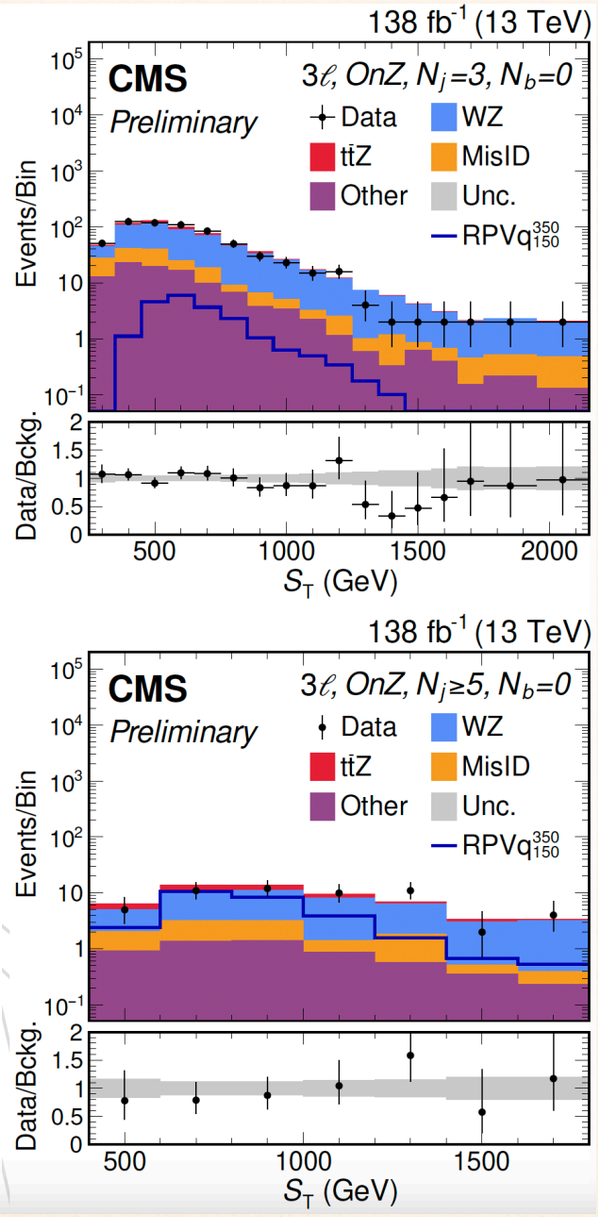
3 lepton selection with corrections, no excess

New!

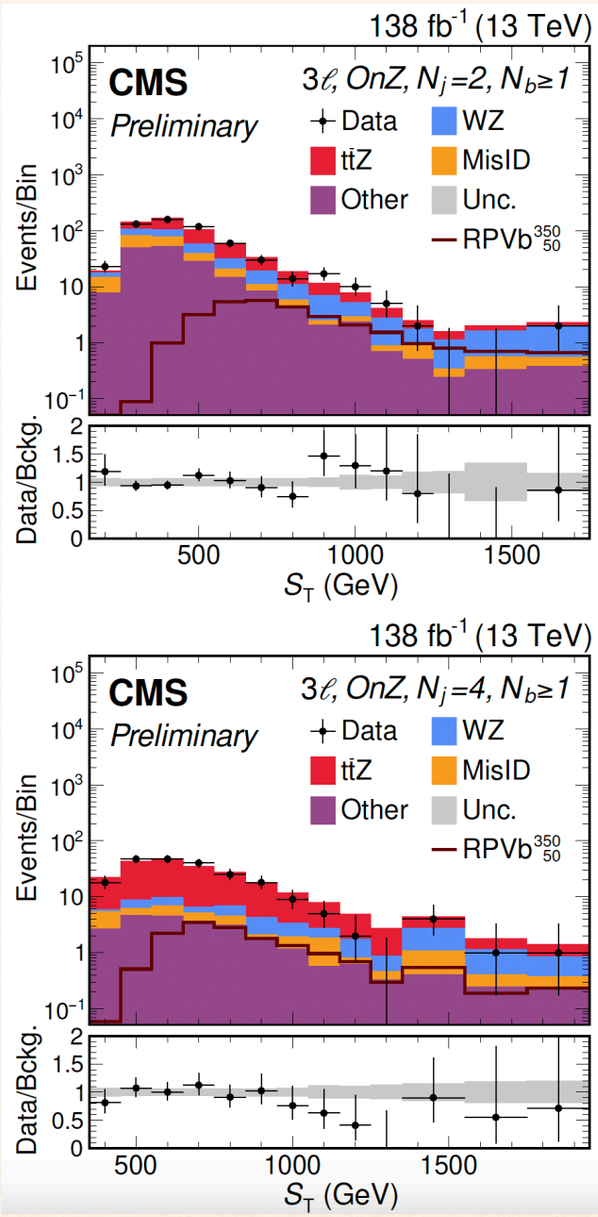
PAS-SUS-23-015

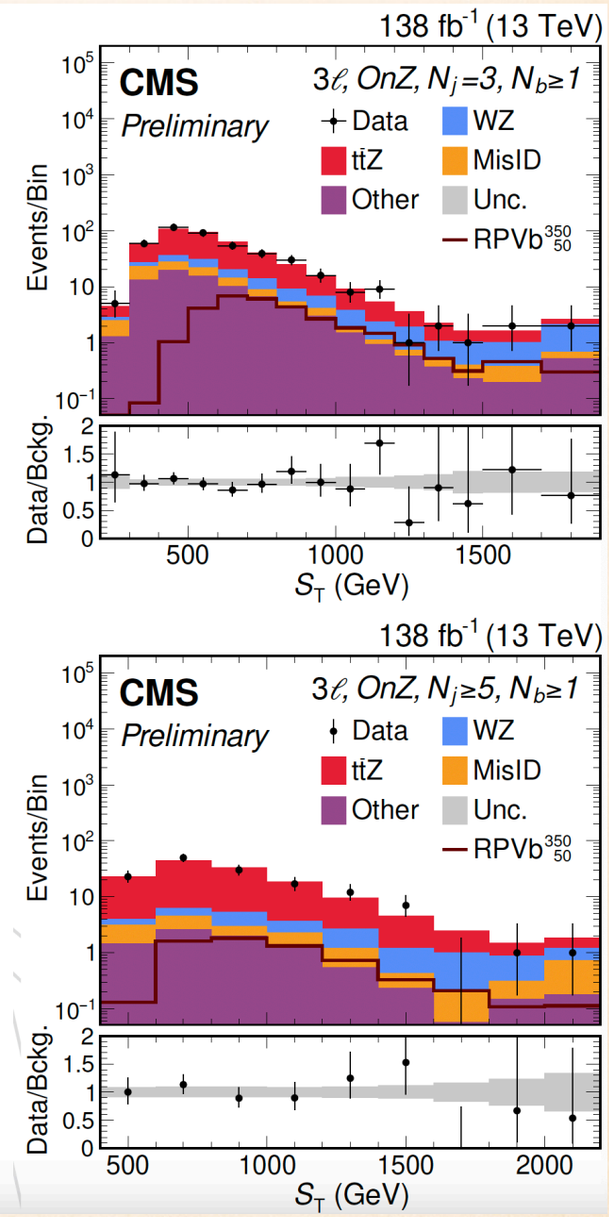
CMS NEW RPV RESULT





channels wo b-jets



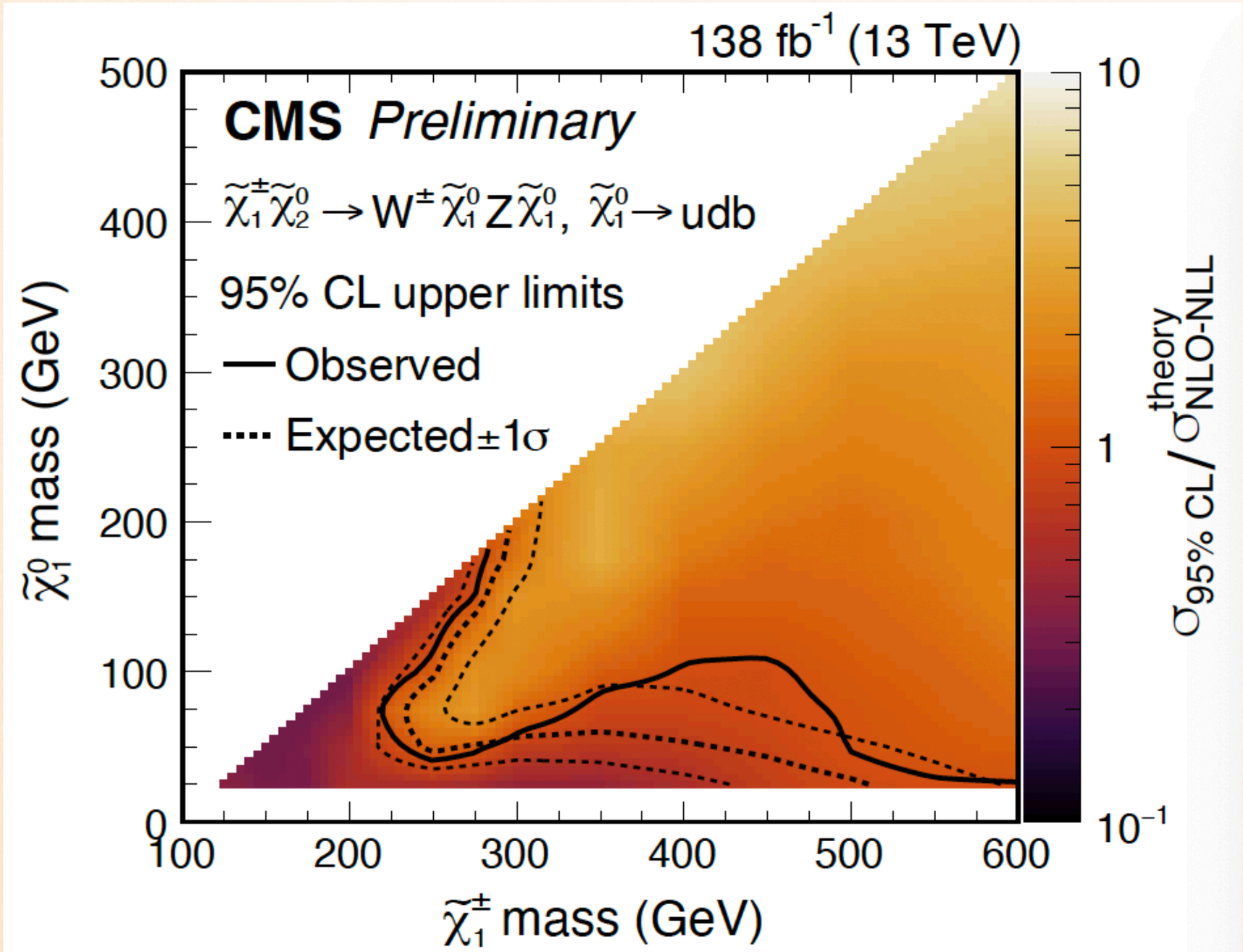


channels with b-jets

New!

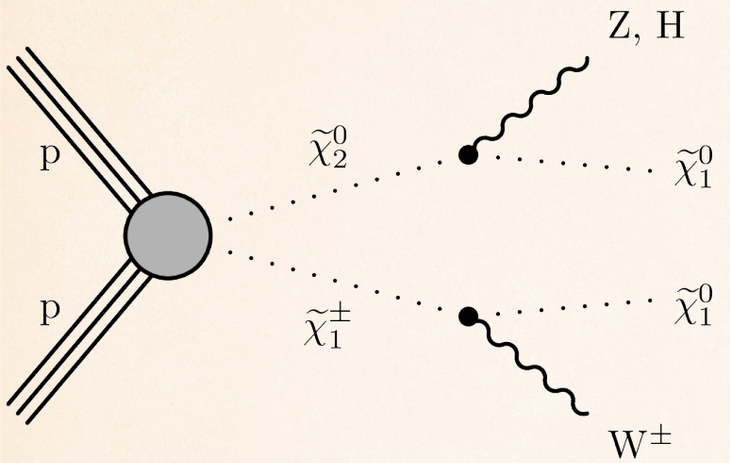
PAS-SUS-23-015

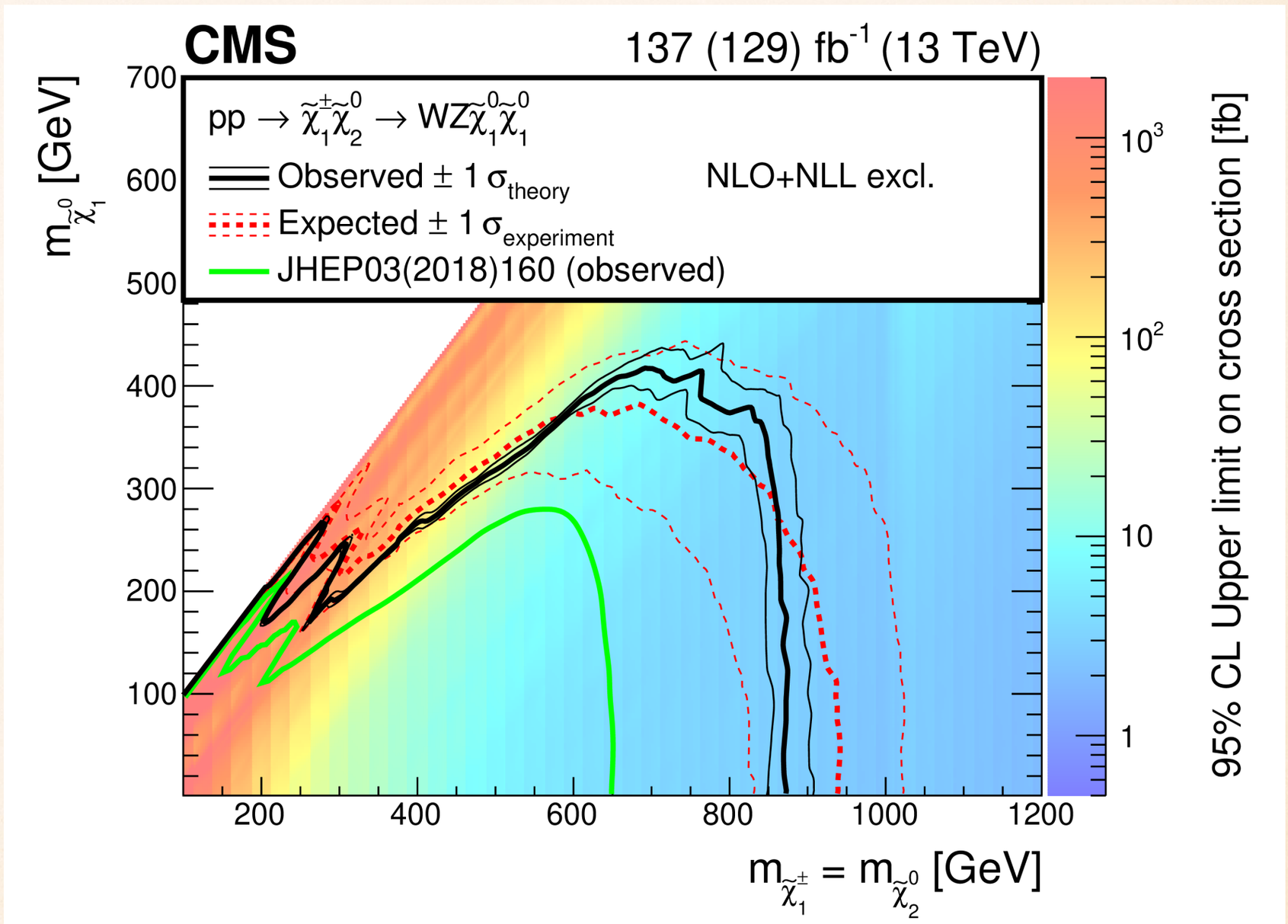
CMS NEW RPV RESULT



arXiv:2402.01888

ELECTROWEAK PRODUCTION

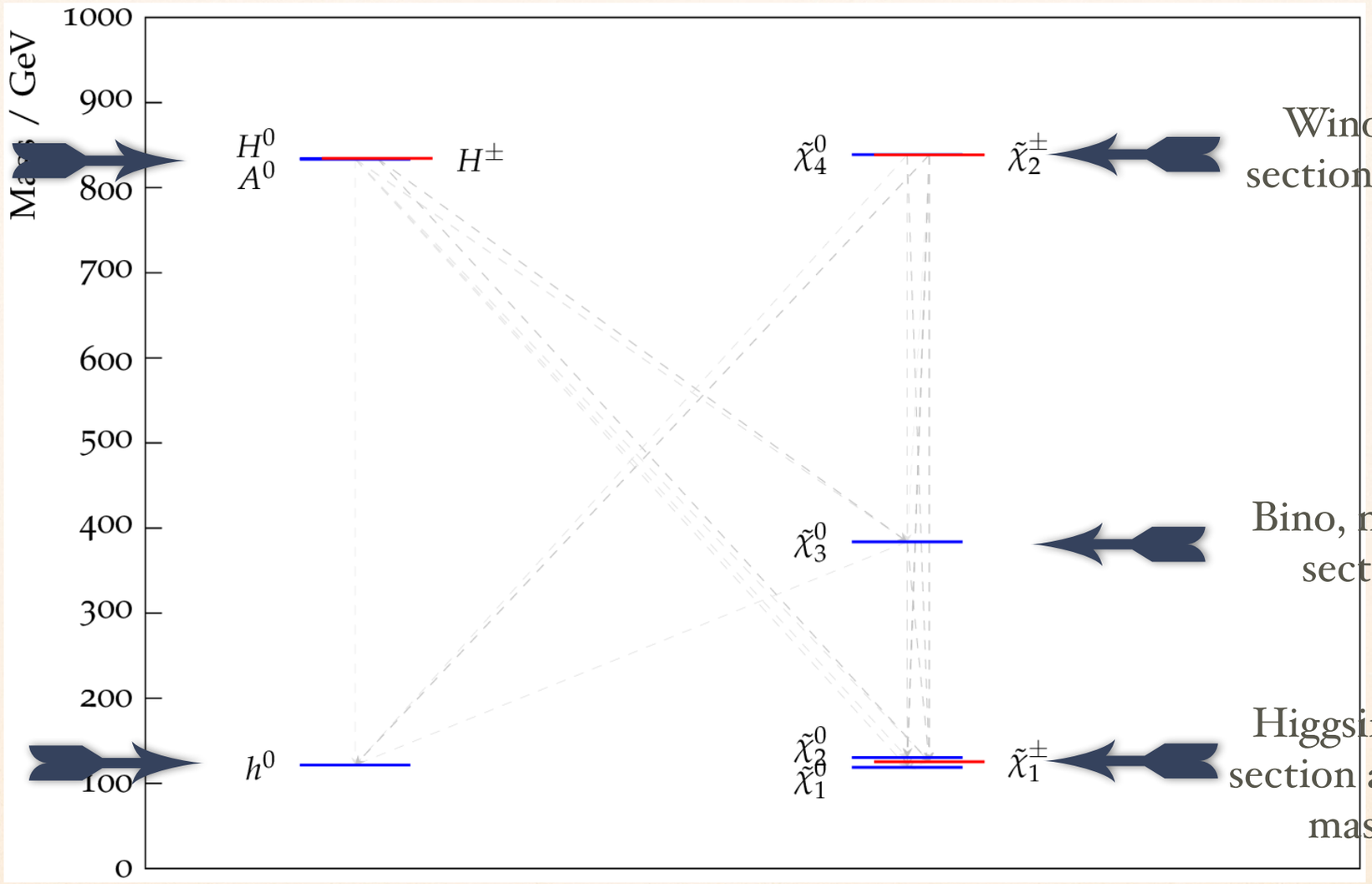




Limits from combination of several analyses.

COMPRESSED SPECTRA

Might be in reach, depending on tan beta and decays to SUSY particles



Wino, small cross section because heavy

Bino, negligible cross section at LHC

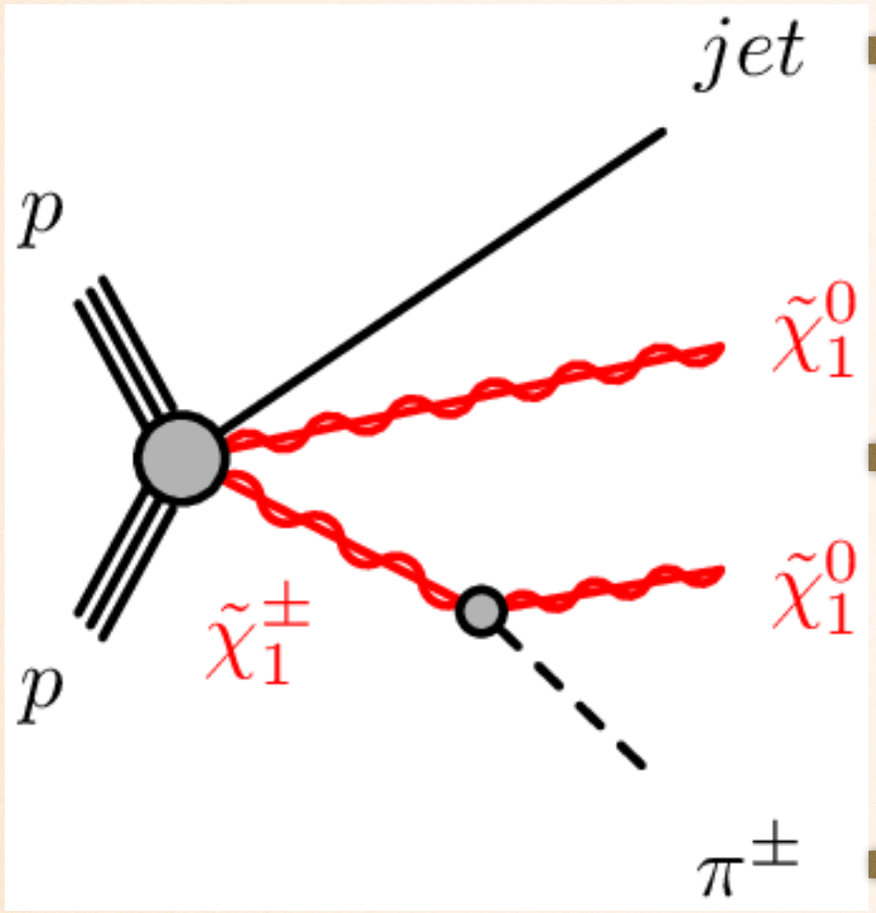
Observed but very similar to SM Higgs

Higgsino, small cross section and compressed mass spectrum

- Other difficult case : EWK production + compressed mass spectrum

arXiv:2401.14046

ATLAS DISPLACED TRACK



1 jet with p_T > 250 GeV

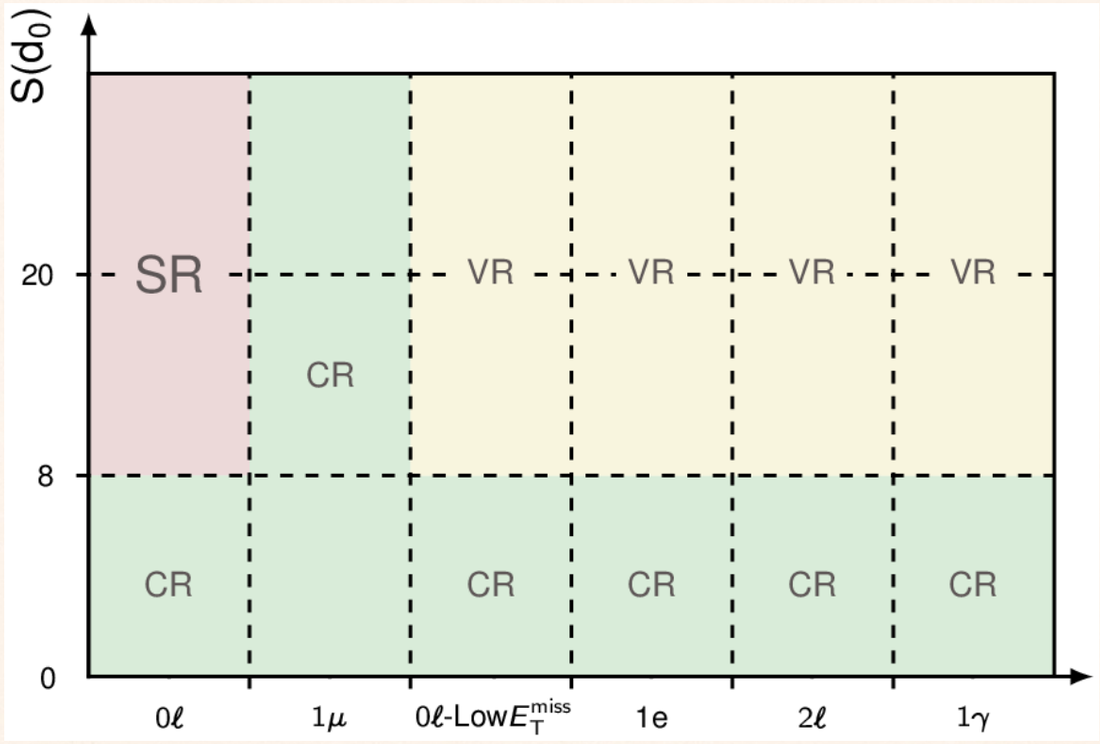
p_T^{miss} > 600 GeV

1 track with 2 < p_T < 5 GeV and significance of impact parameter $S(d_o)$ > 8

For $\Delta M(\chi^\pm,\chi^0)$ =0.5 GeV, $c\tau$ = 4 mm

arXiv:2401.14046

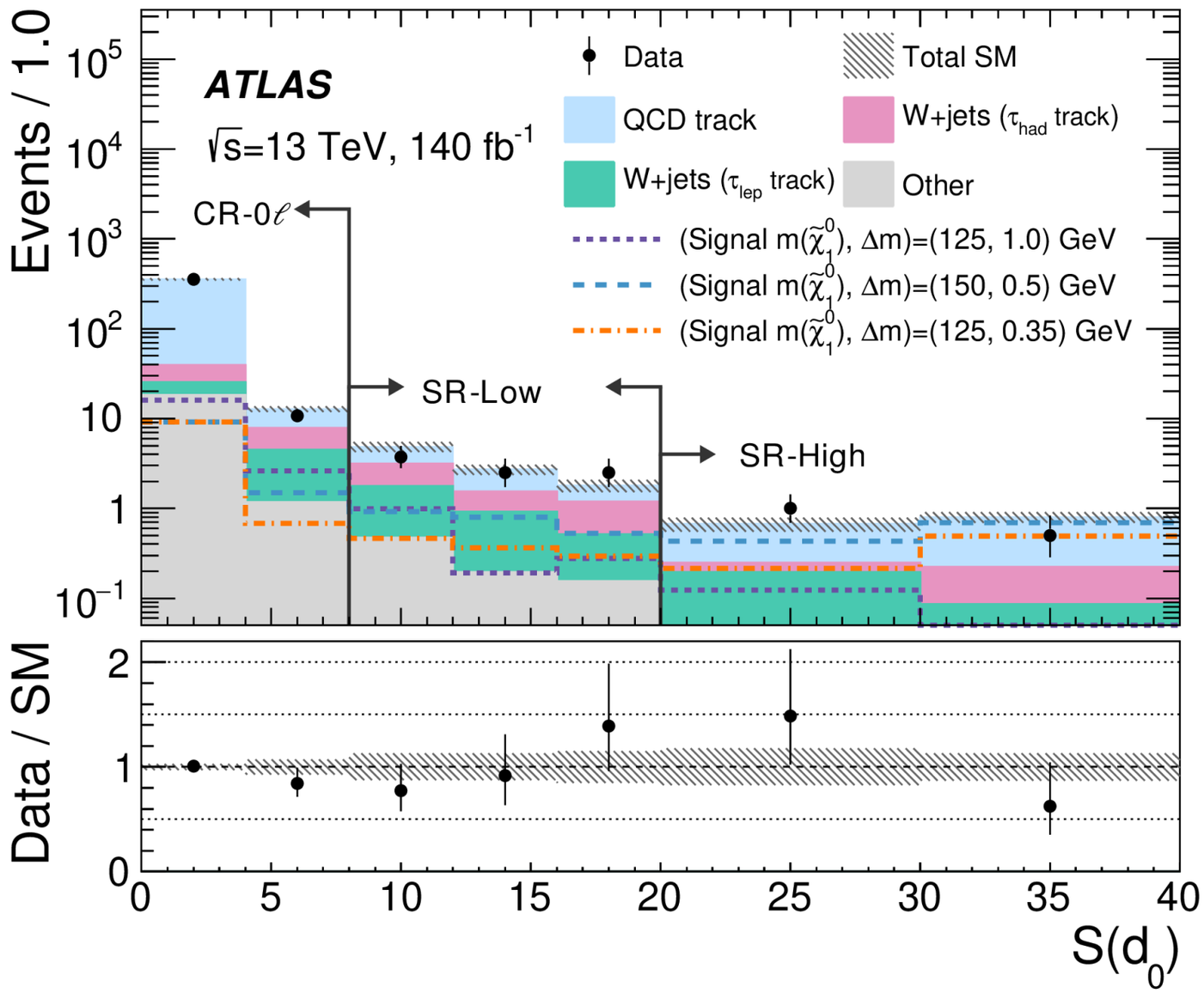
ATLAS DISPLACED TRACK



- QCD tracks (Mostly from $Z \to \nu\nu$ events) estimated with data driven method : Sd_0 shape is the same in 0L and 1L ($W \to \mu\nu$ events) control selection
- Tracks from $W \to \tau\nu$ events : MC normalized to control region at higher track p_T

arXiv:2401.14046

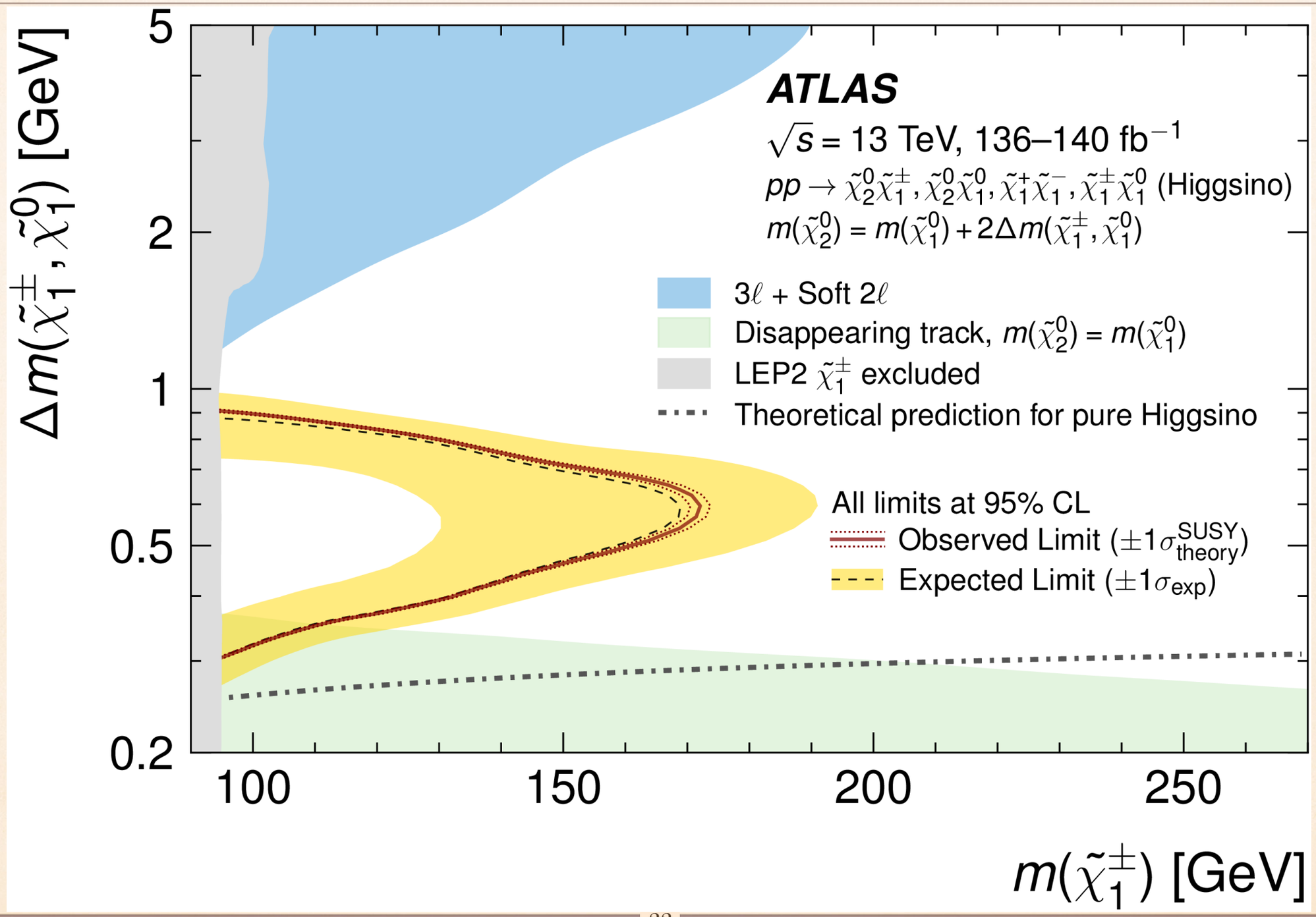
ATLAS DISPLACED TRACK



- Two bins in Sd_0 (sensitive to lower/higher Δm)
- No excess in either

arXiv:2401.14046

ATLAS DISPLACED TRACK

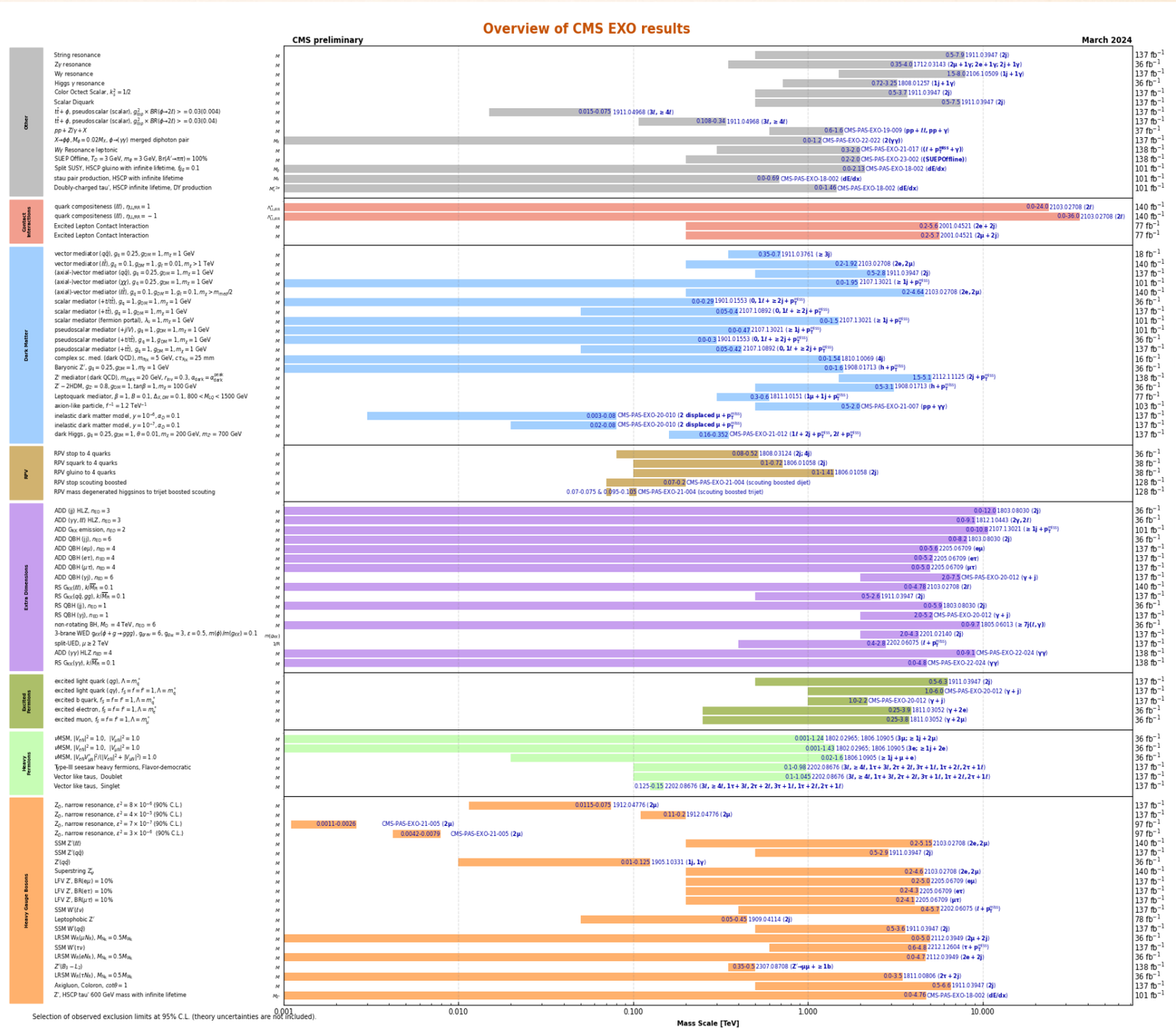


CONCLUSIONS

We haven't found it. **Yet**

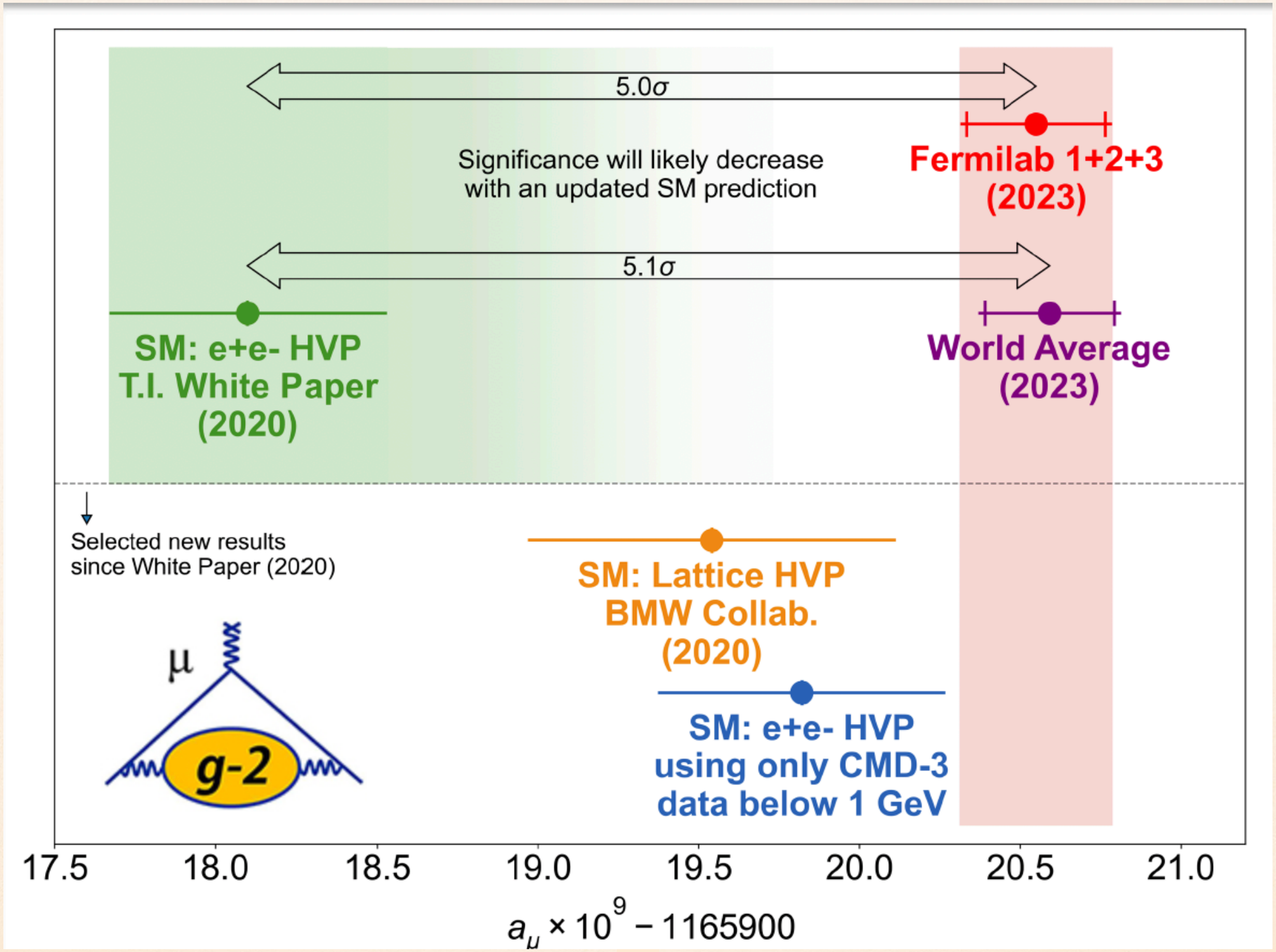
LHC is providing more data and we keep looking in many places

Stay tuned !

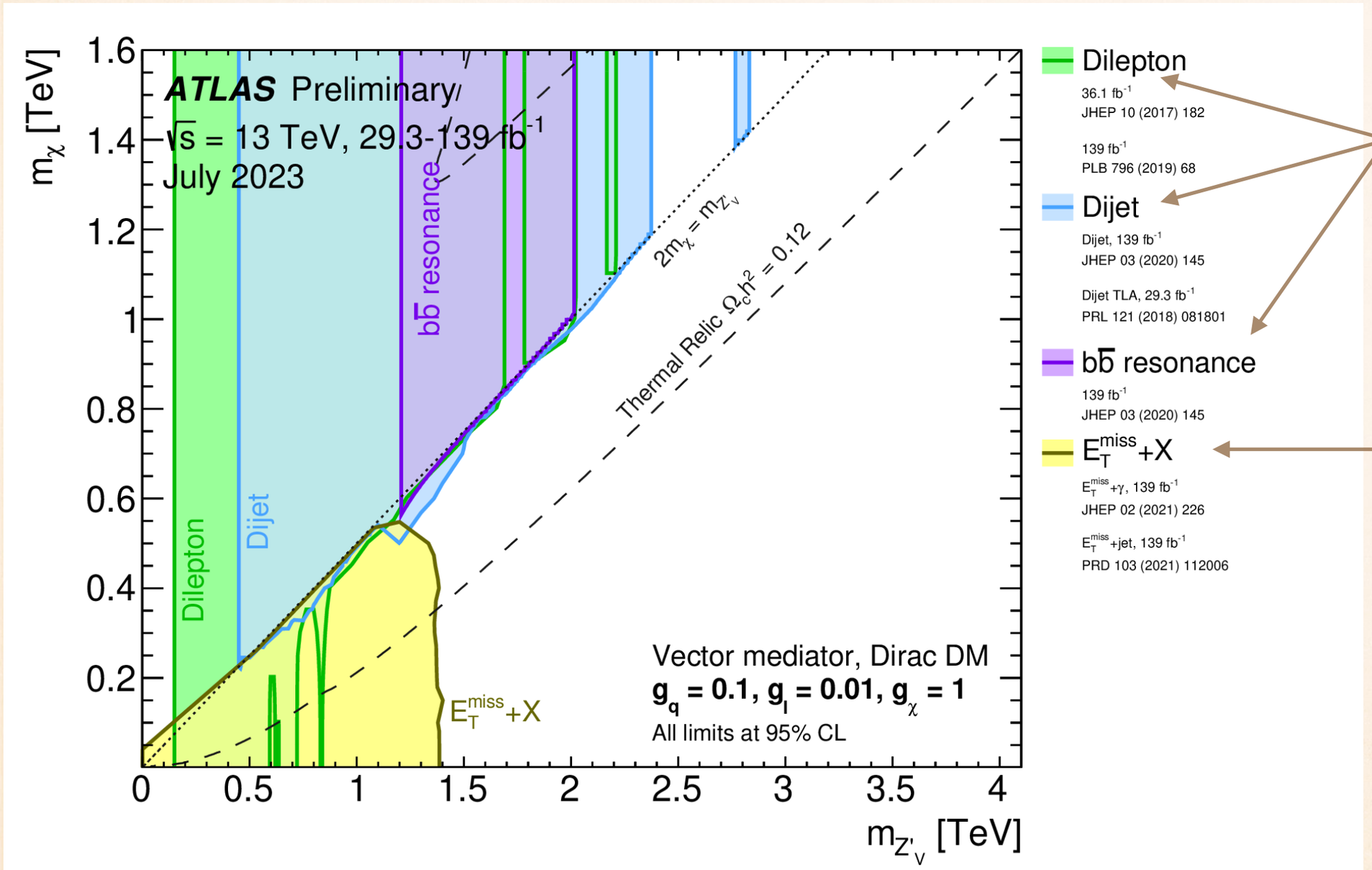


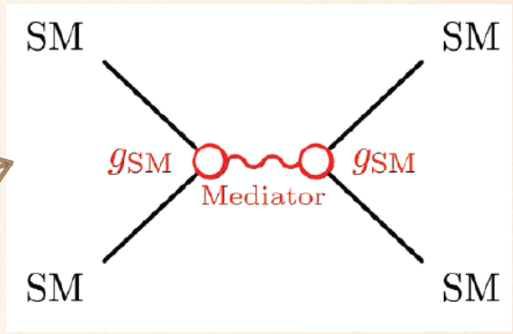
BACKUP

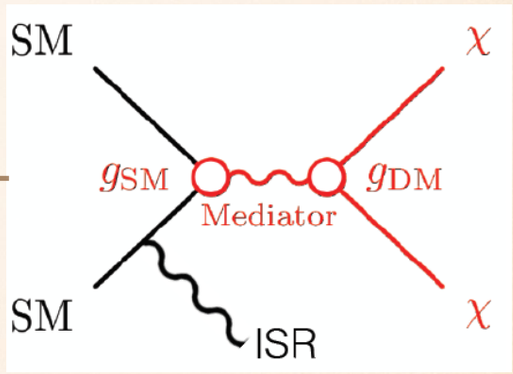
...with a few exceptions that gives us hope, but are not yet confirmed as definitely coming from non-SM physics



S-CHANNEL SPIN 1 MEDIATOR

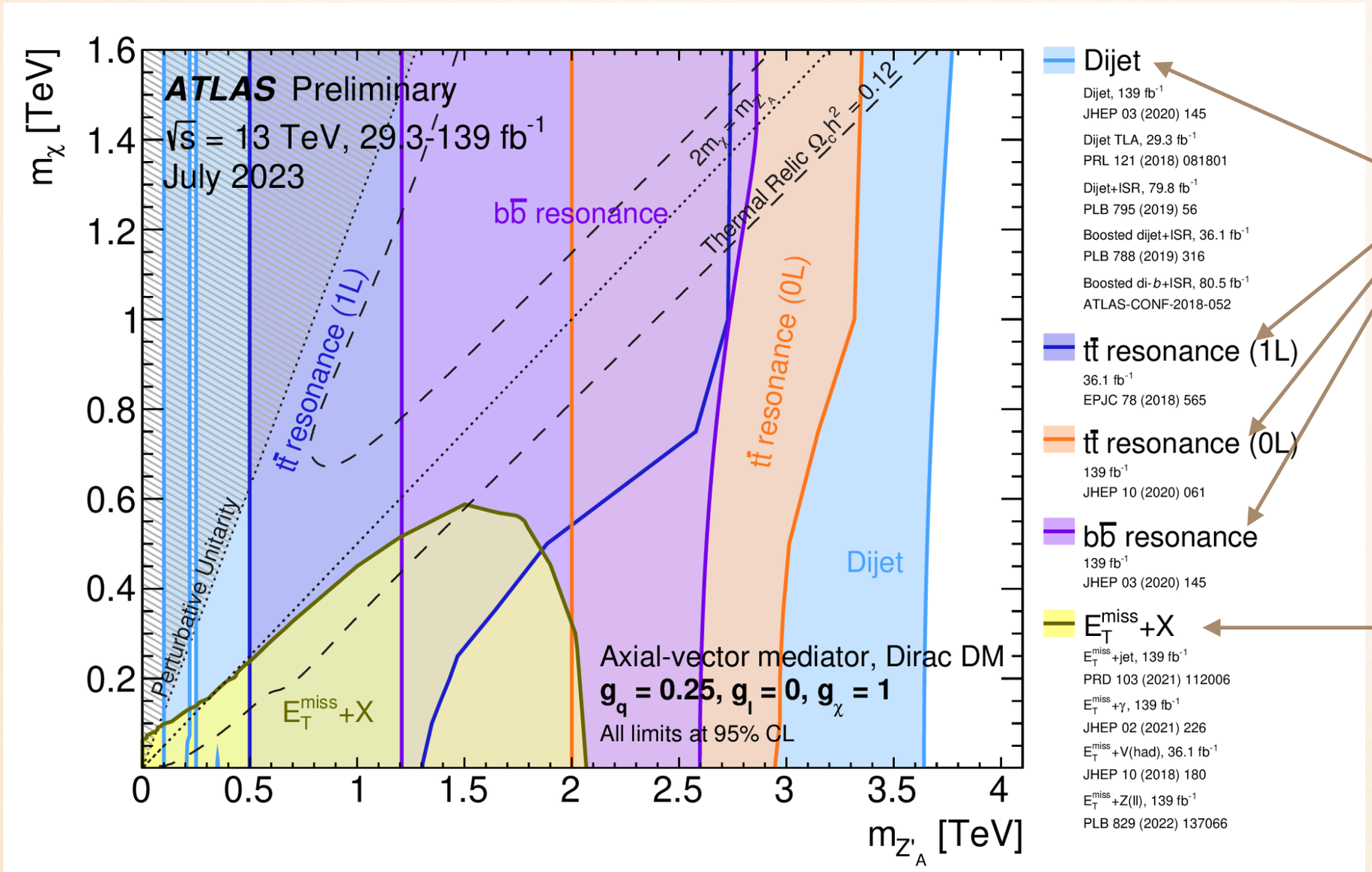


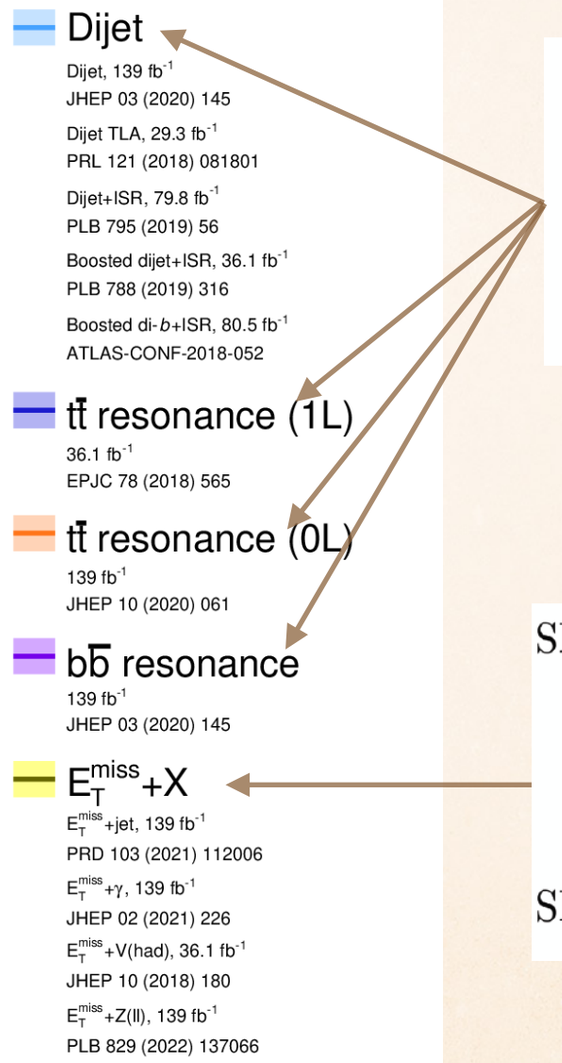


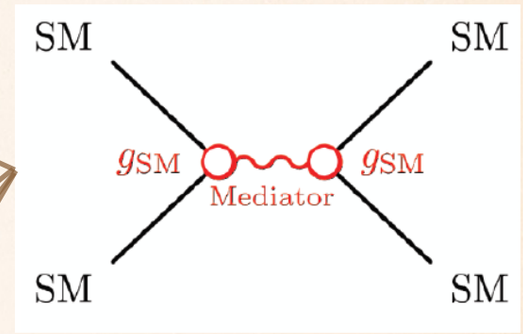


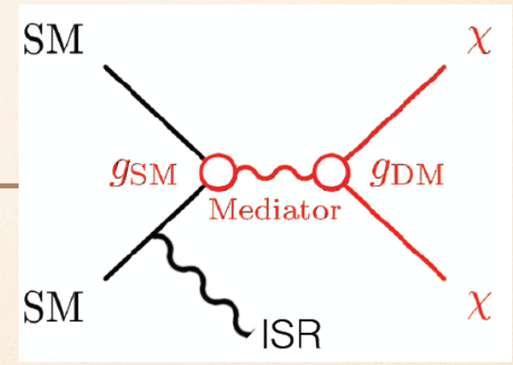
DM production best channel when DM mass < 0.5 mediator mass and $g_{SM} << g_{DM}$

S-CHANNEL SPIN 1 MEDIATOR



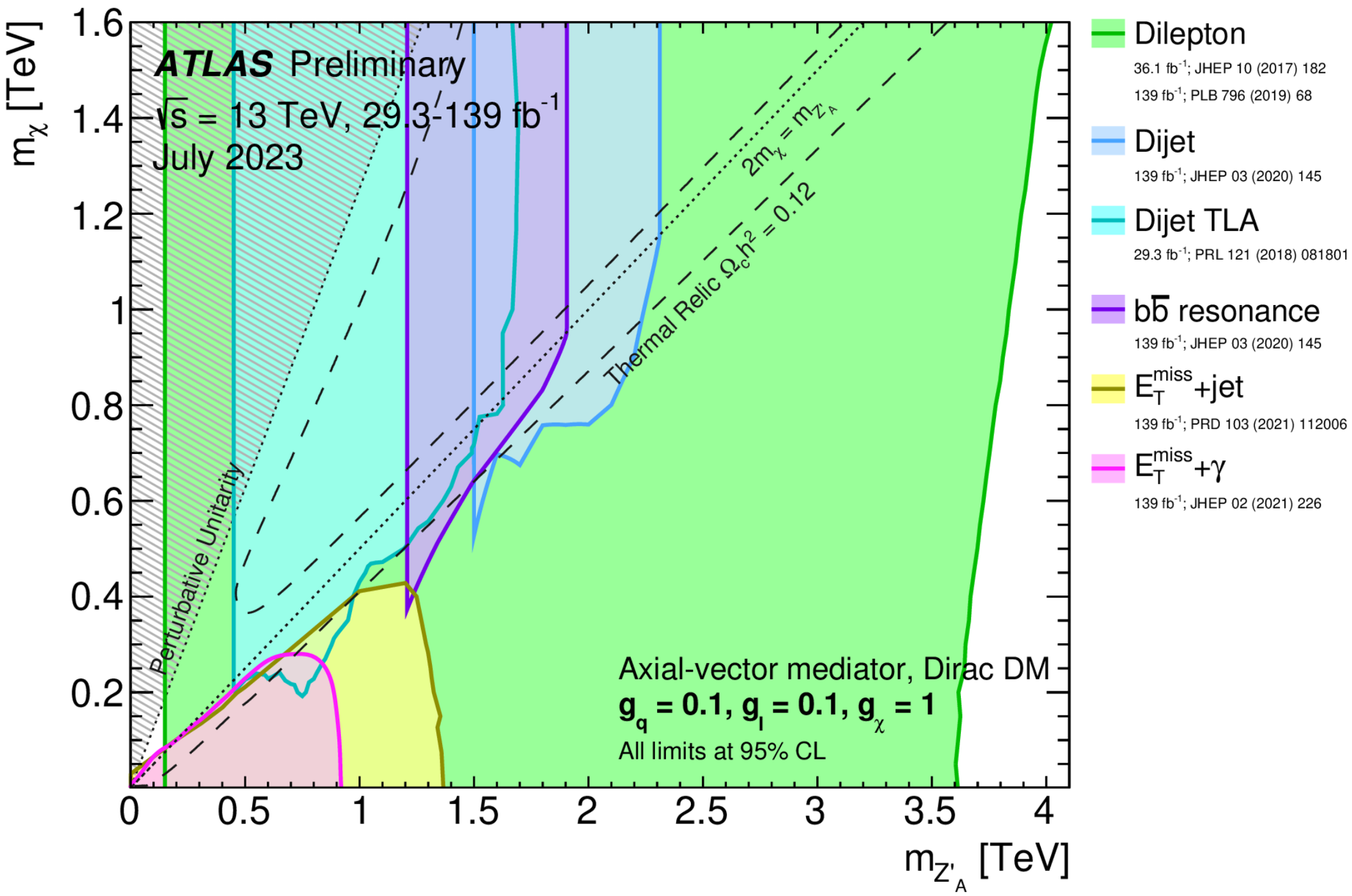




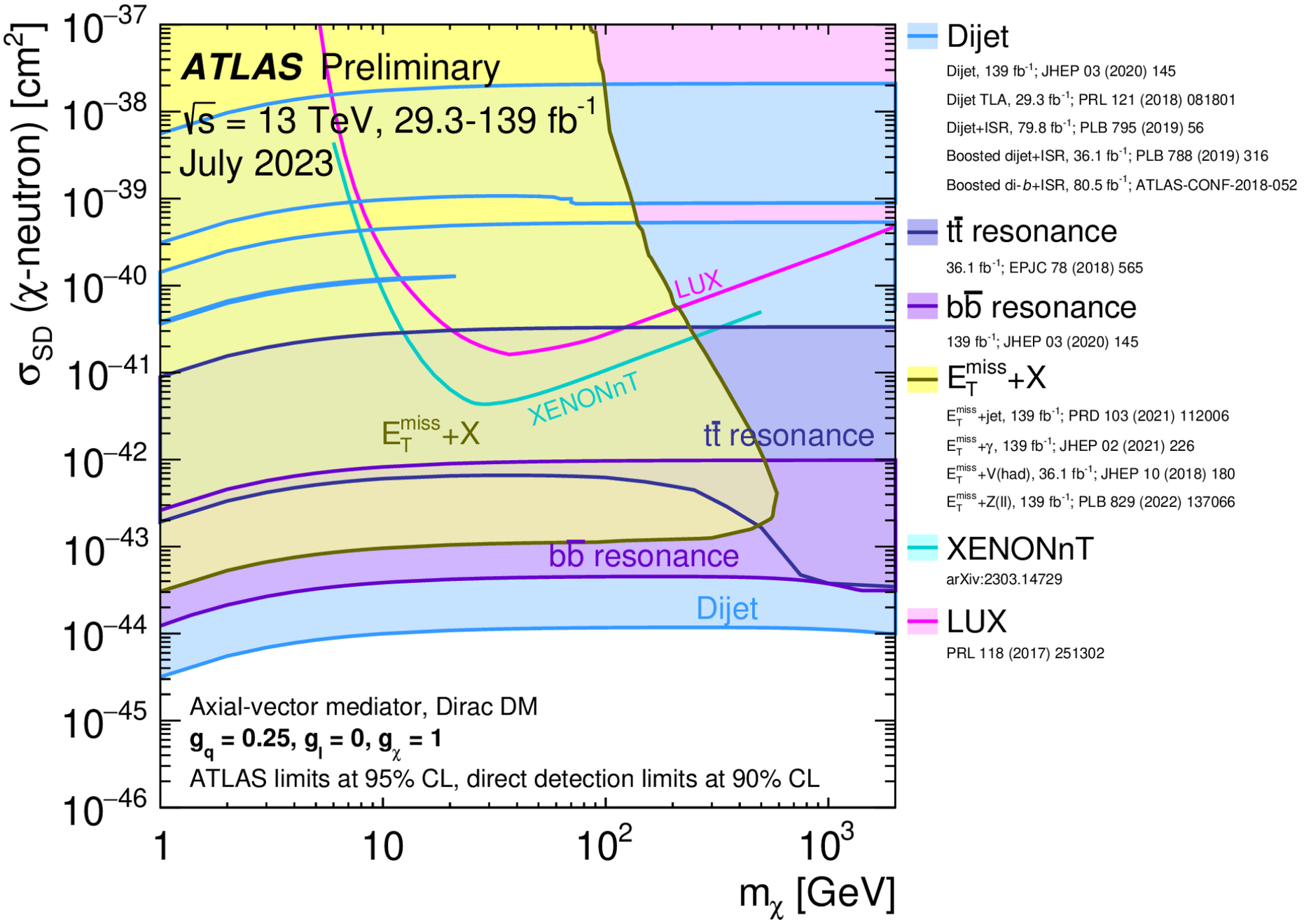


CMS DM summary plots

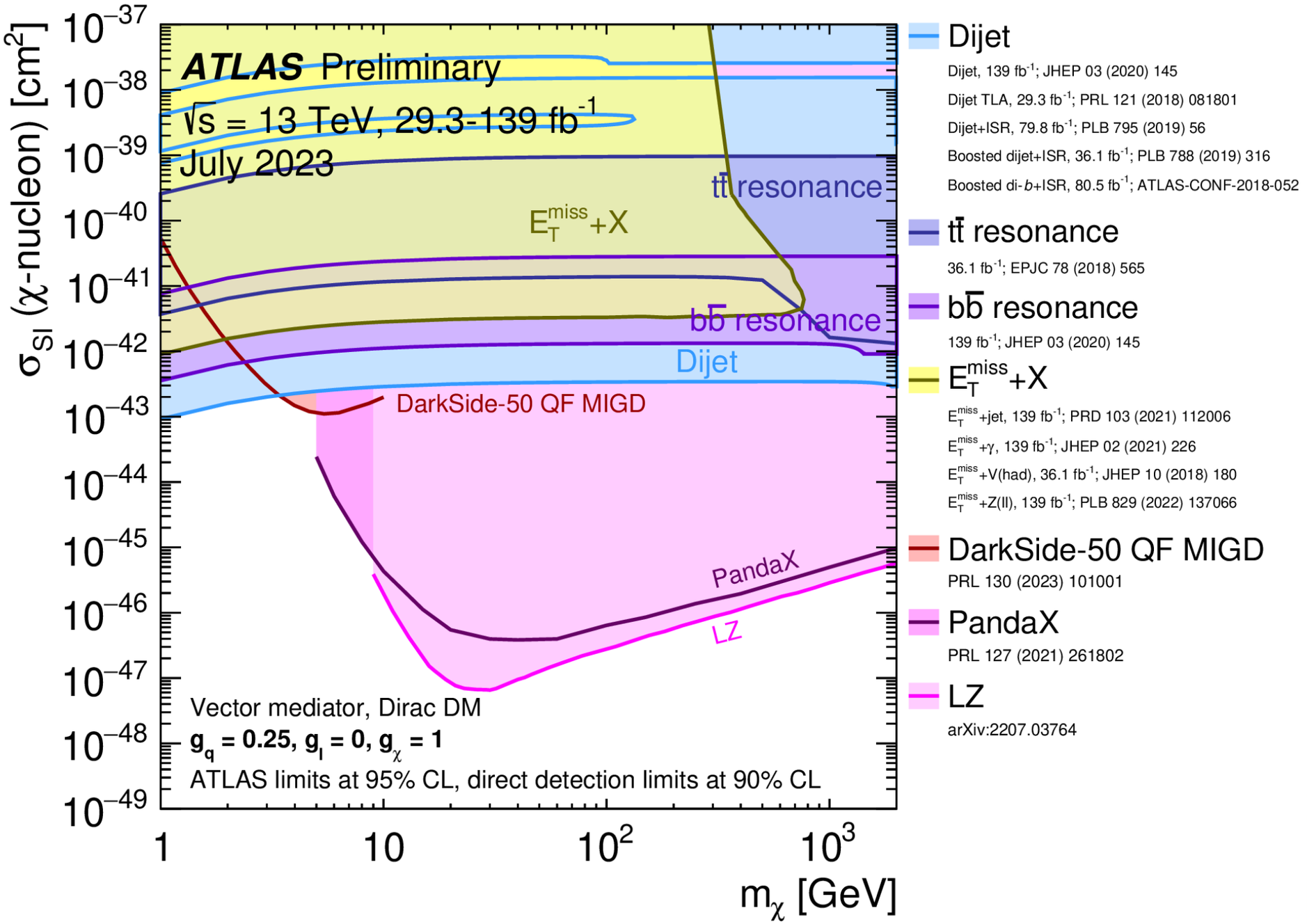
DM SUMMARY PLOTS



ATLAS AND SD DIRECT SEARCHES

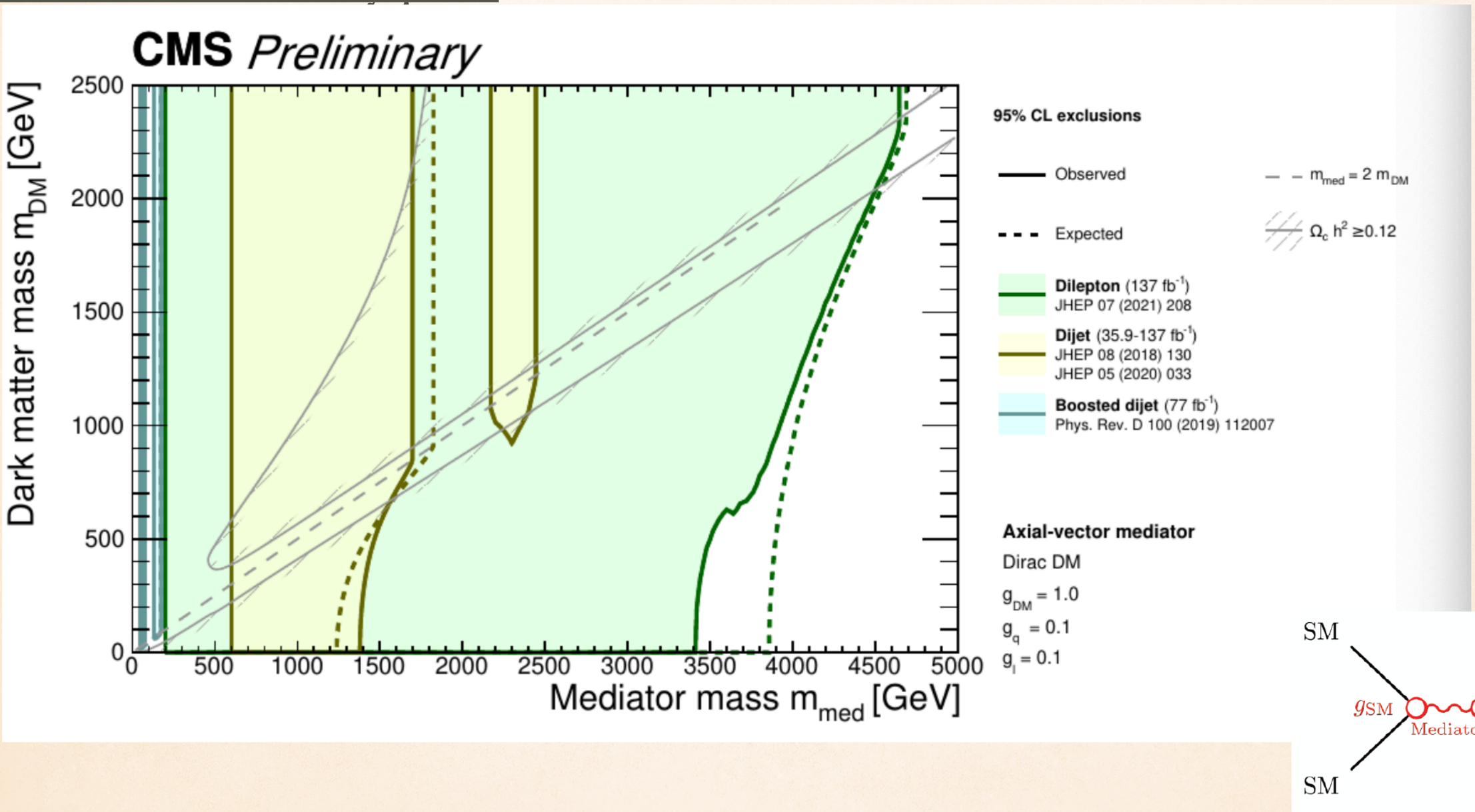


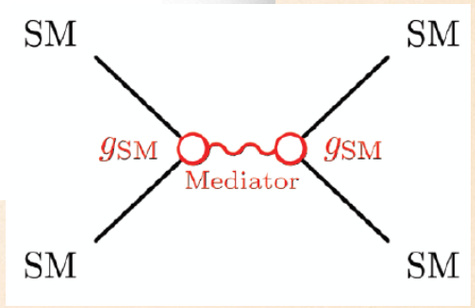
ATLAS AND SI DIRECT SEARCHES



S-CHANNEL SPIN 1 MEDIATOR

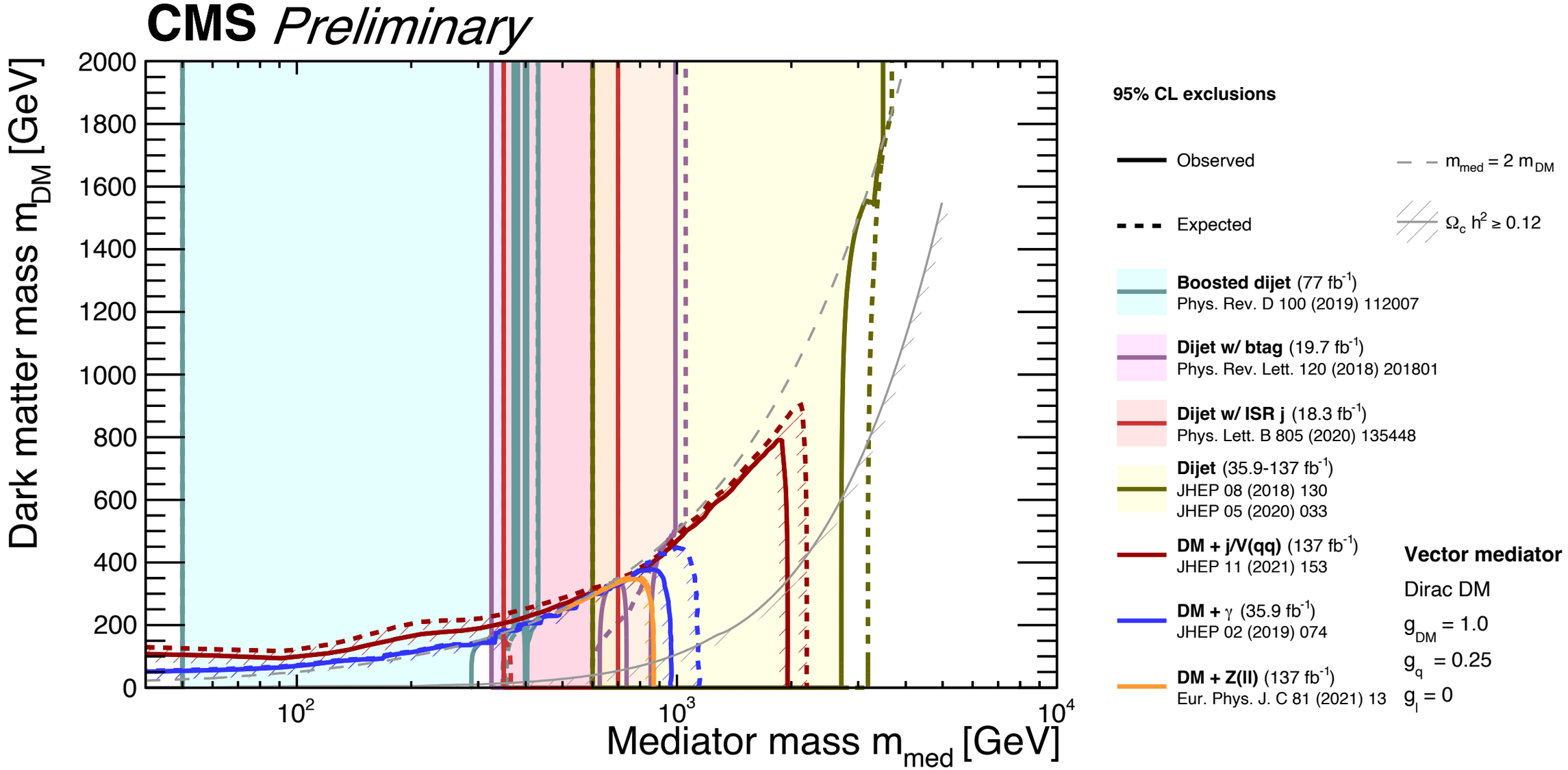
CMS DM summary plots





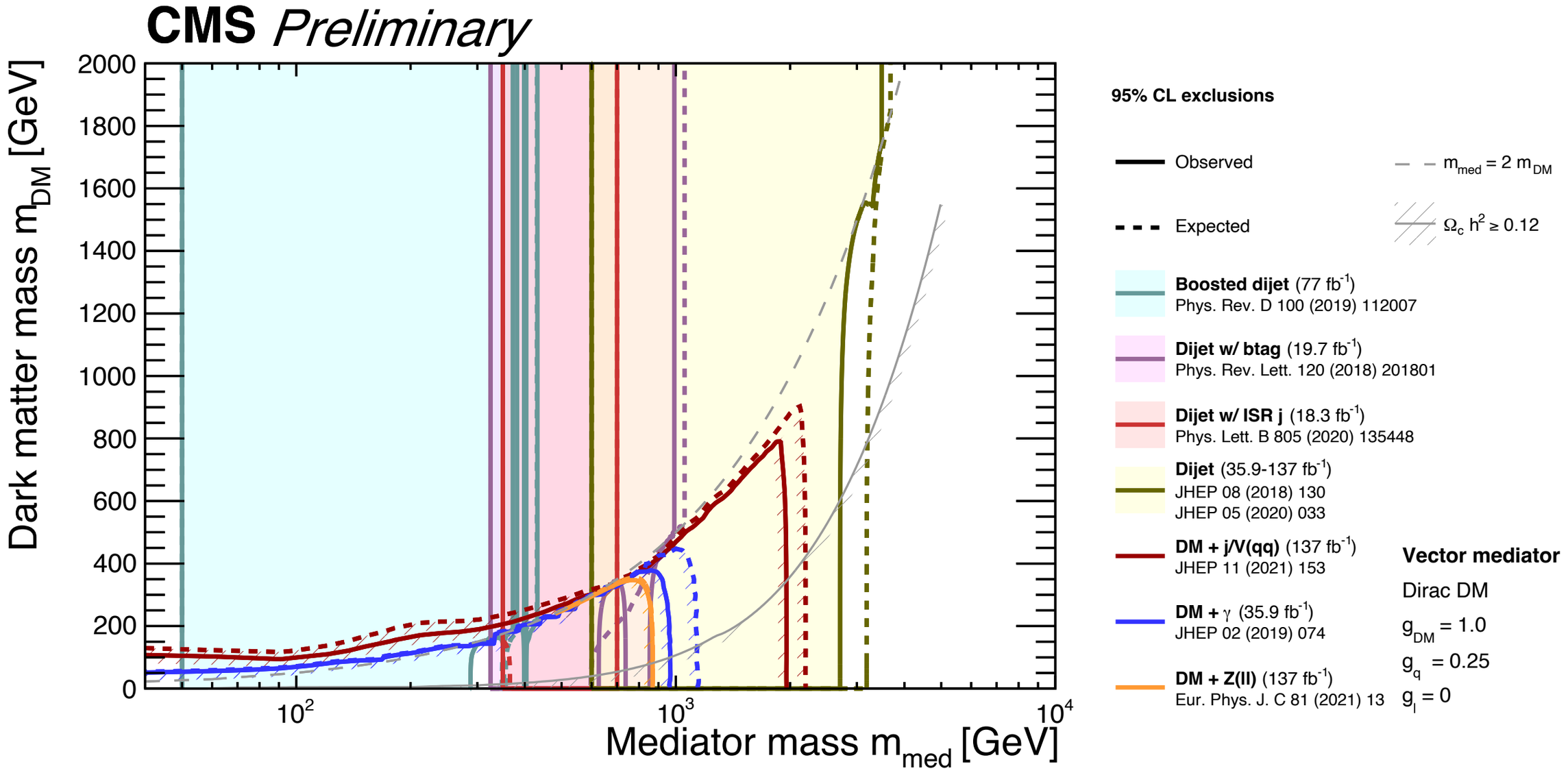
S-CHANNEL SPIN 1 MEDIATOR

CMS DM summary plots



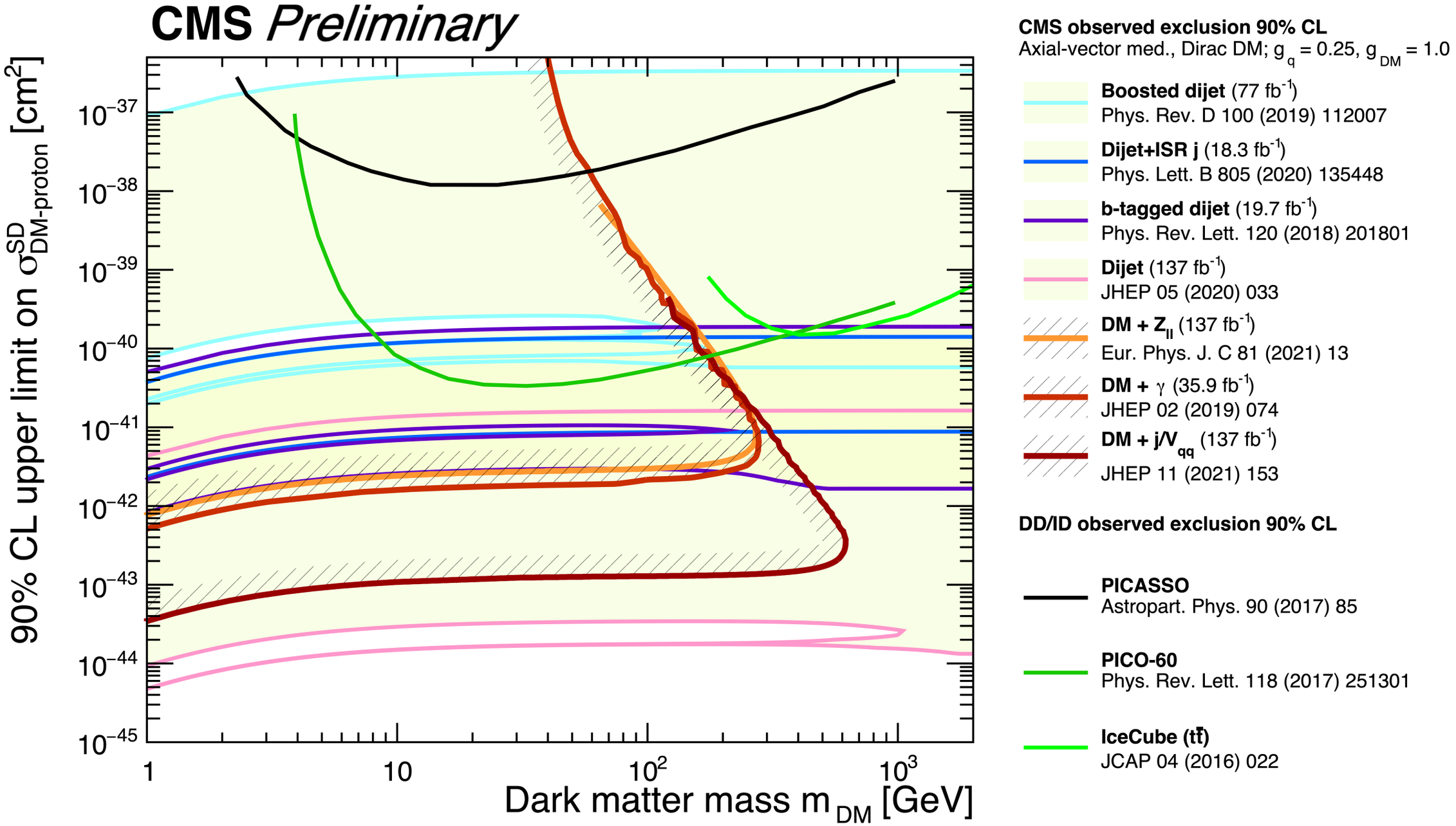
S-CHANNEL SPIN 1 MEDIATOR

CMS DM summary plots



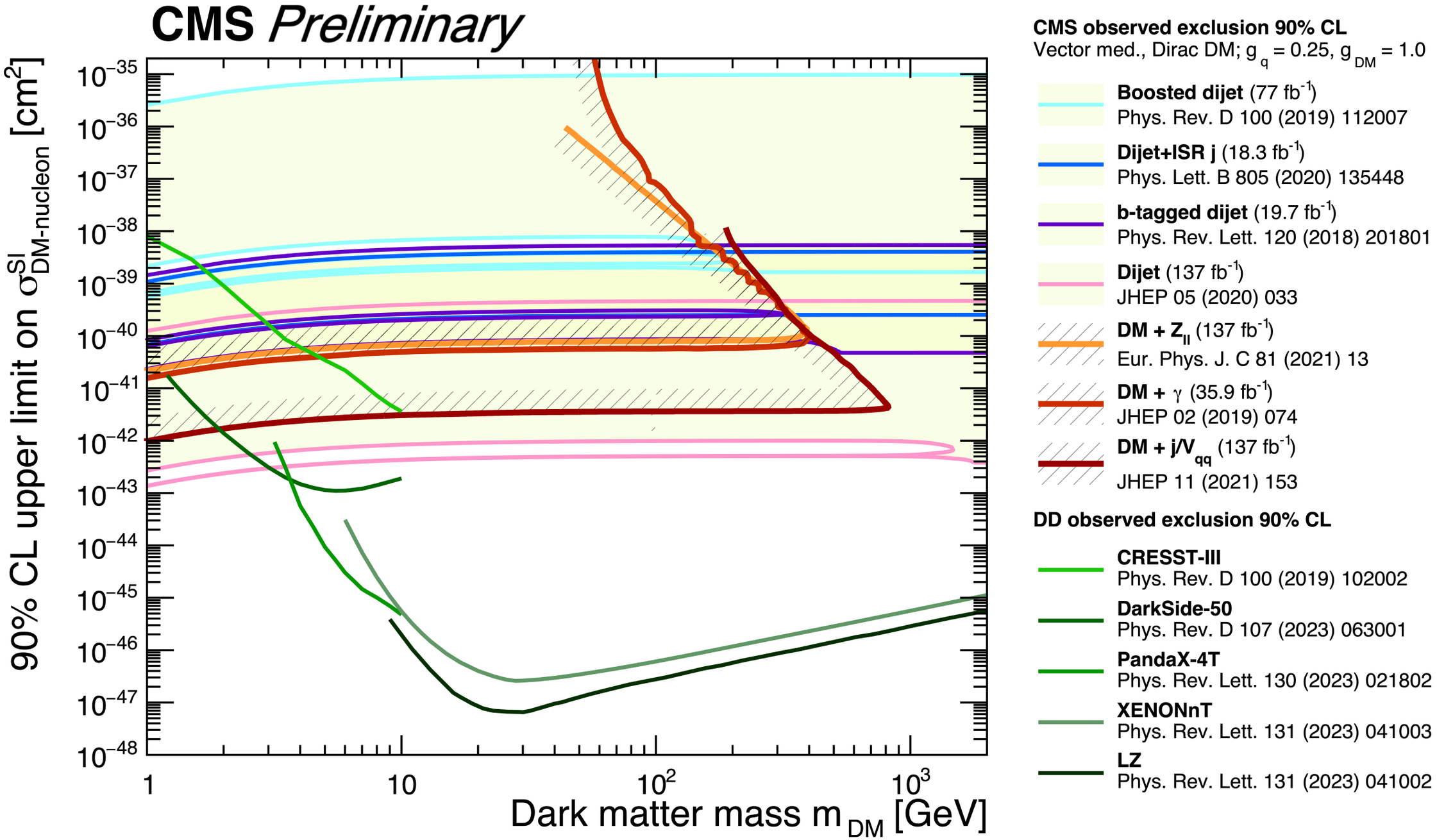
CMS LIMITS RECASTED IN SD-MASS PLANE

CMS DM summary plots



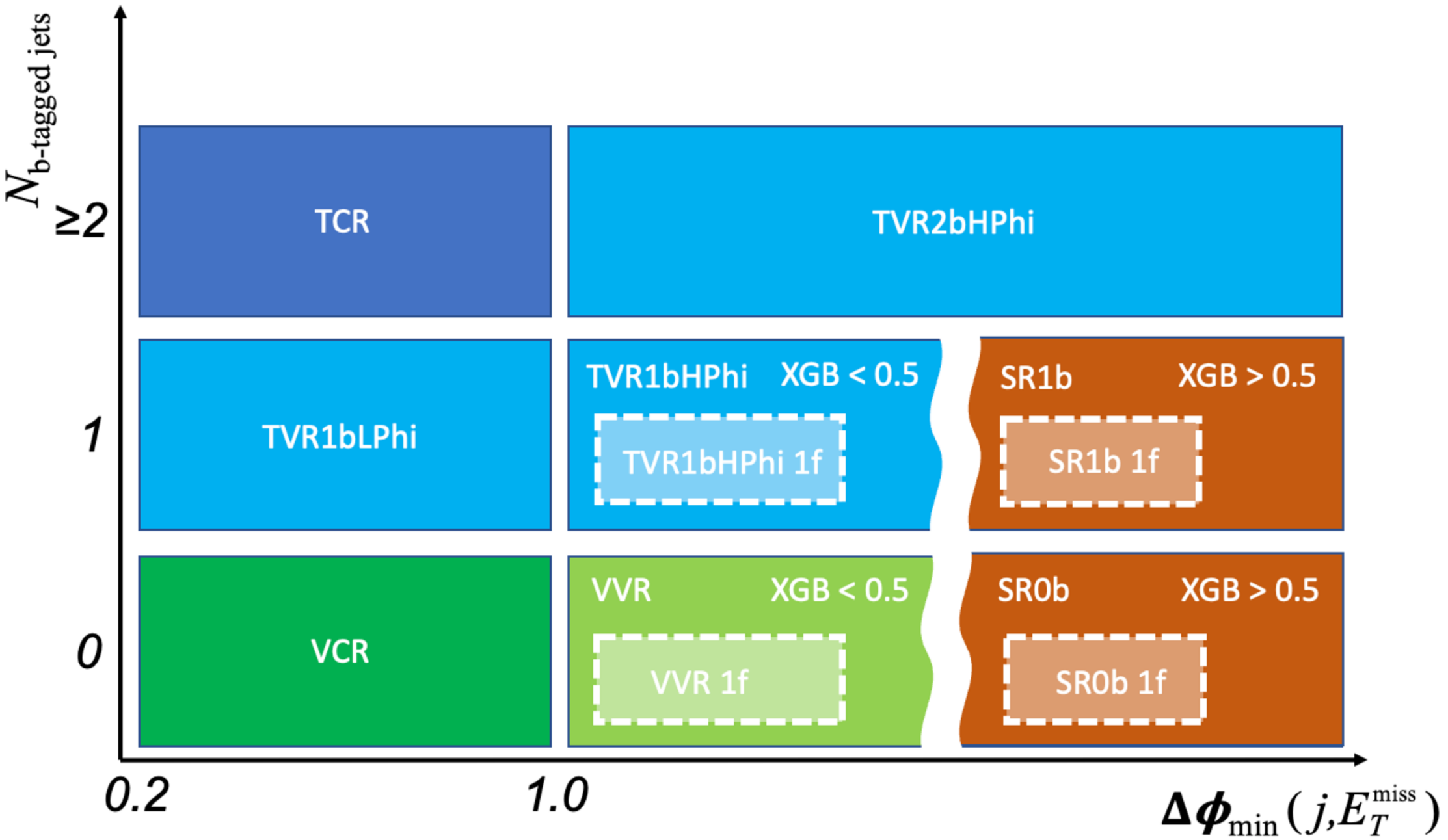
CMS LIMITS RECASTED IN SI-MASS PLANE

CMS DM summary plots



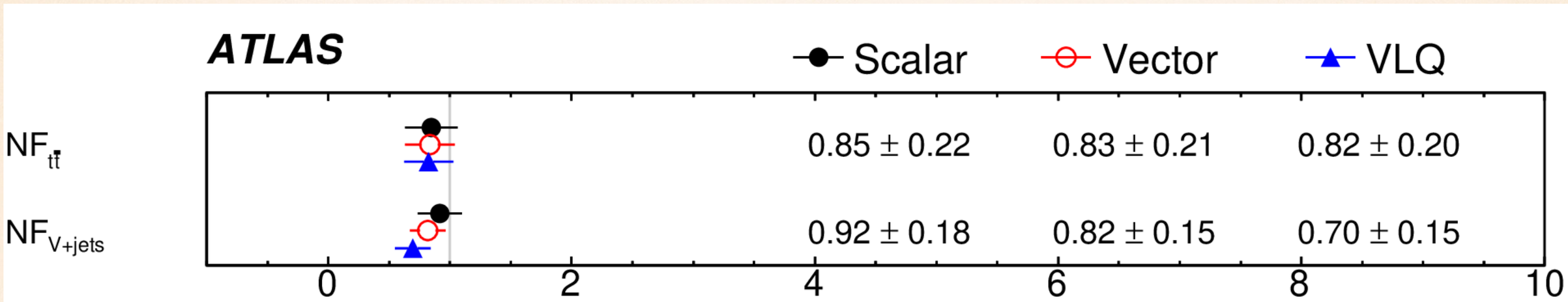
arXiv:2402.16561

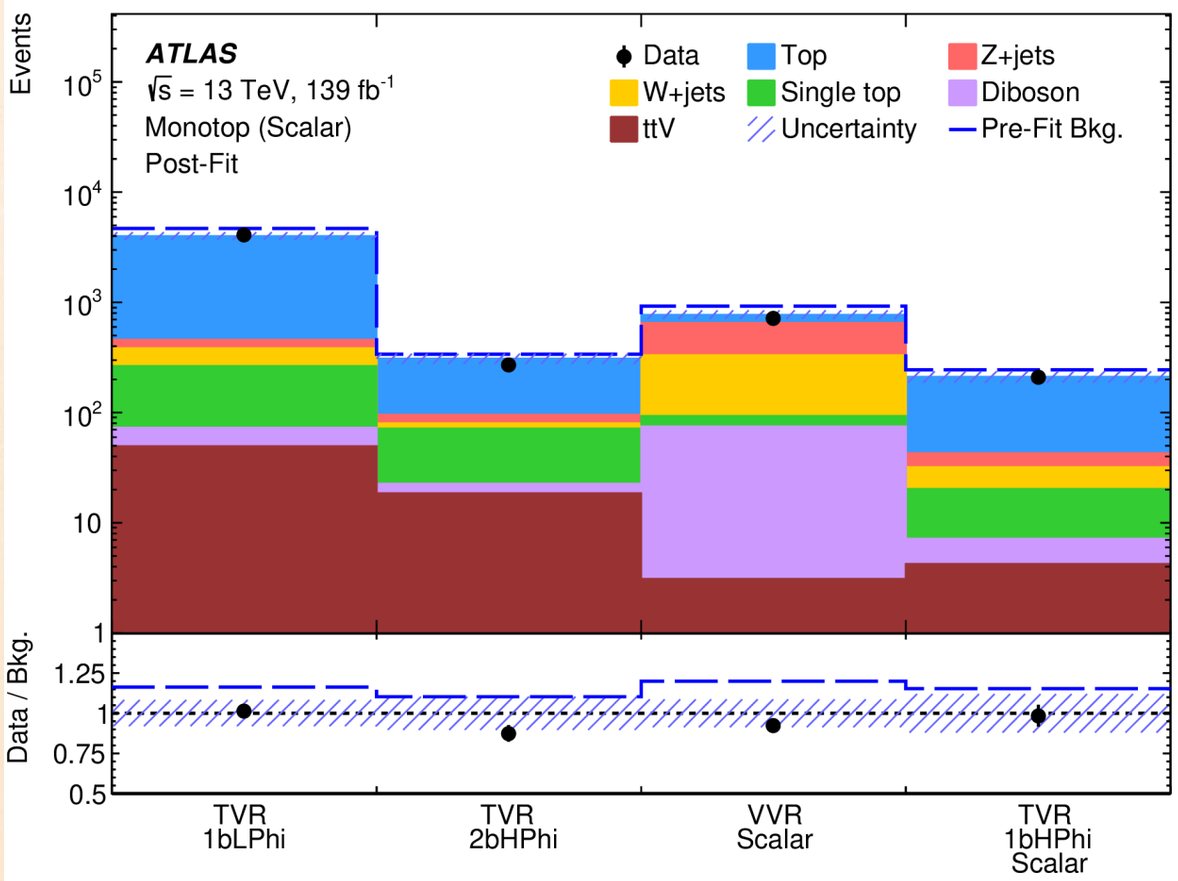
MONOTOP CONTROL AND VALIDATION REGIONS

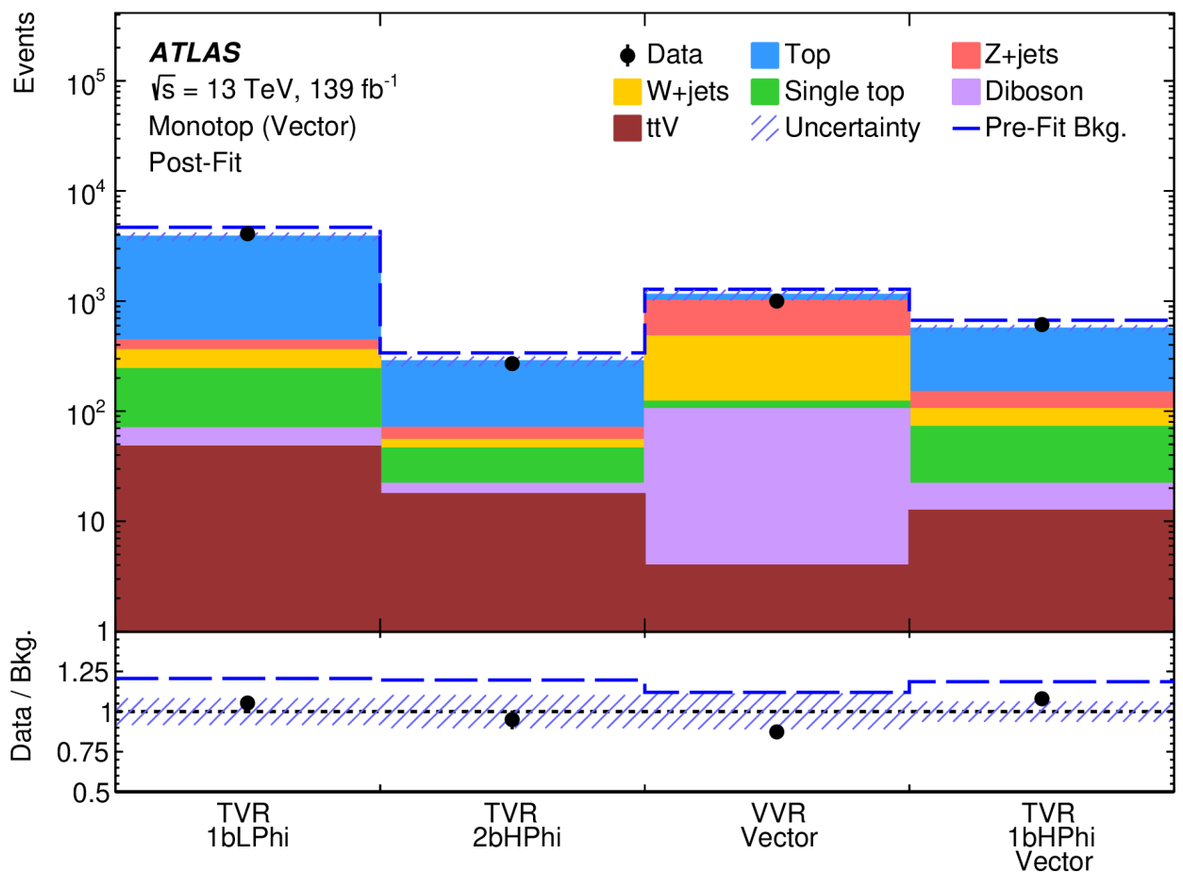


arXiv:2402.16561

MONOTOP VALIDATION REGIONS

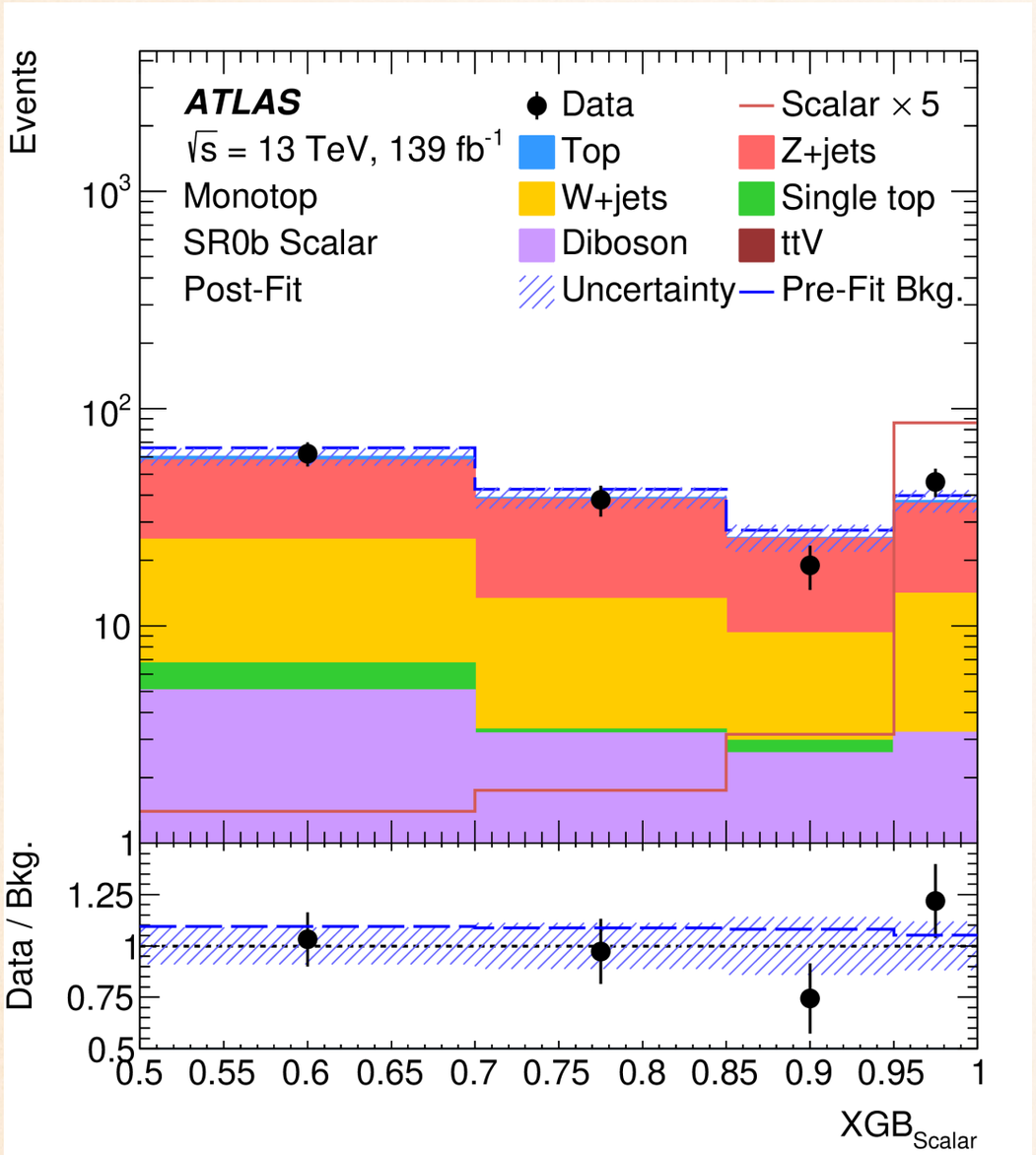


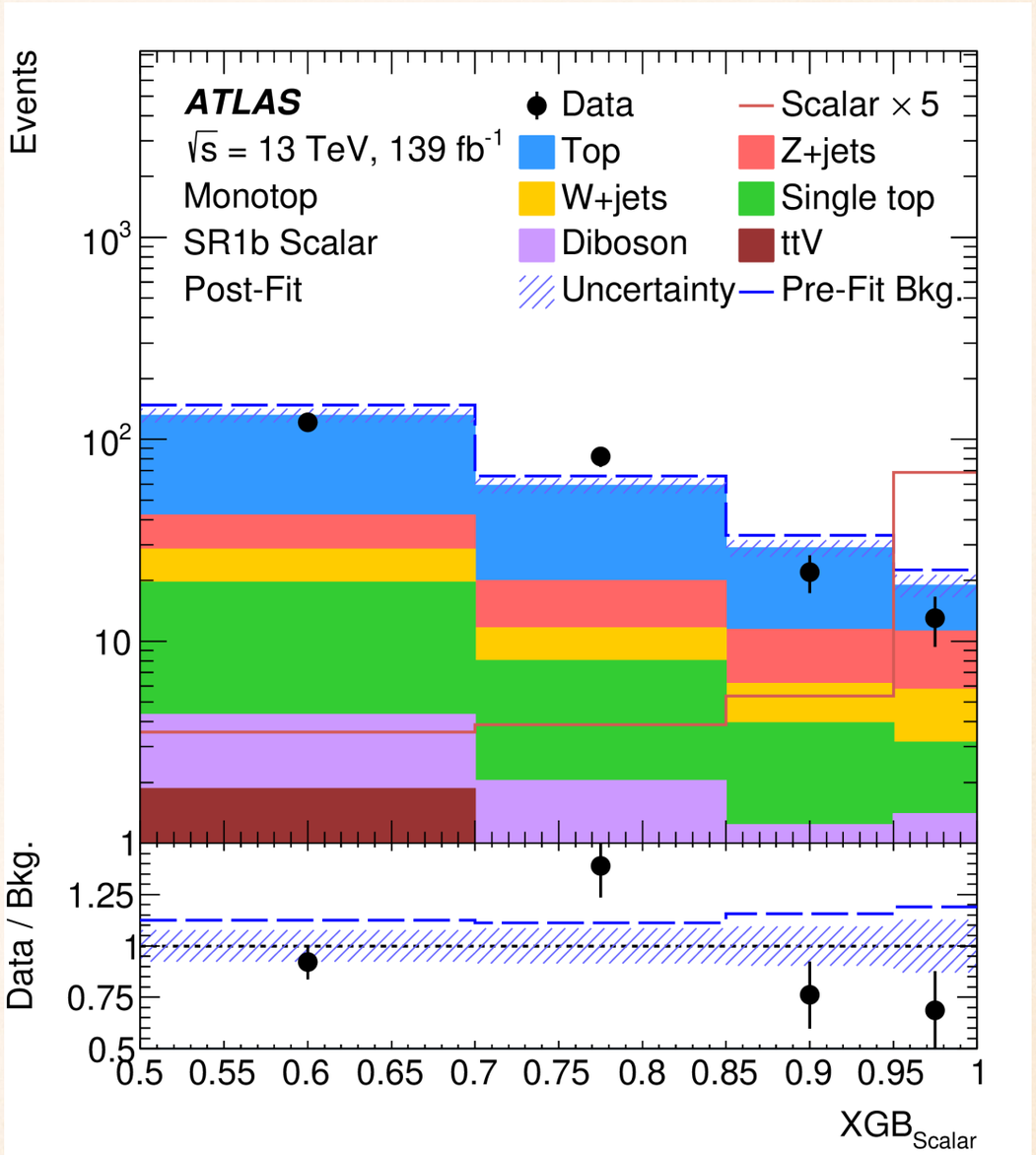




arXiv:2402.16561

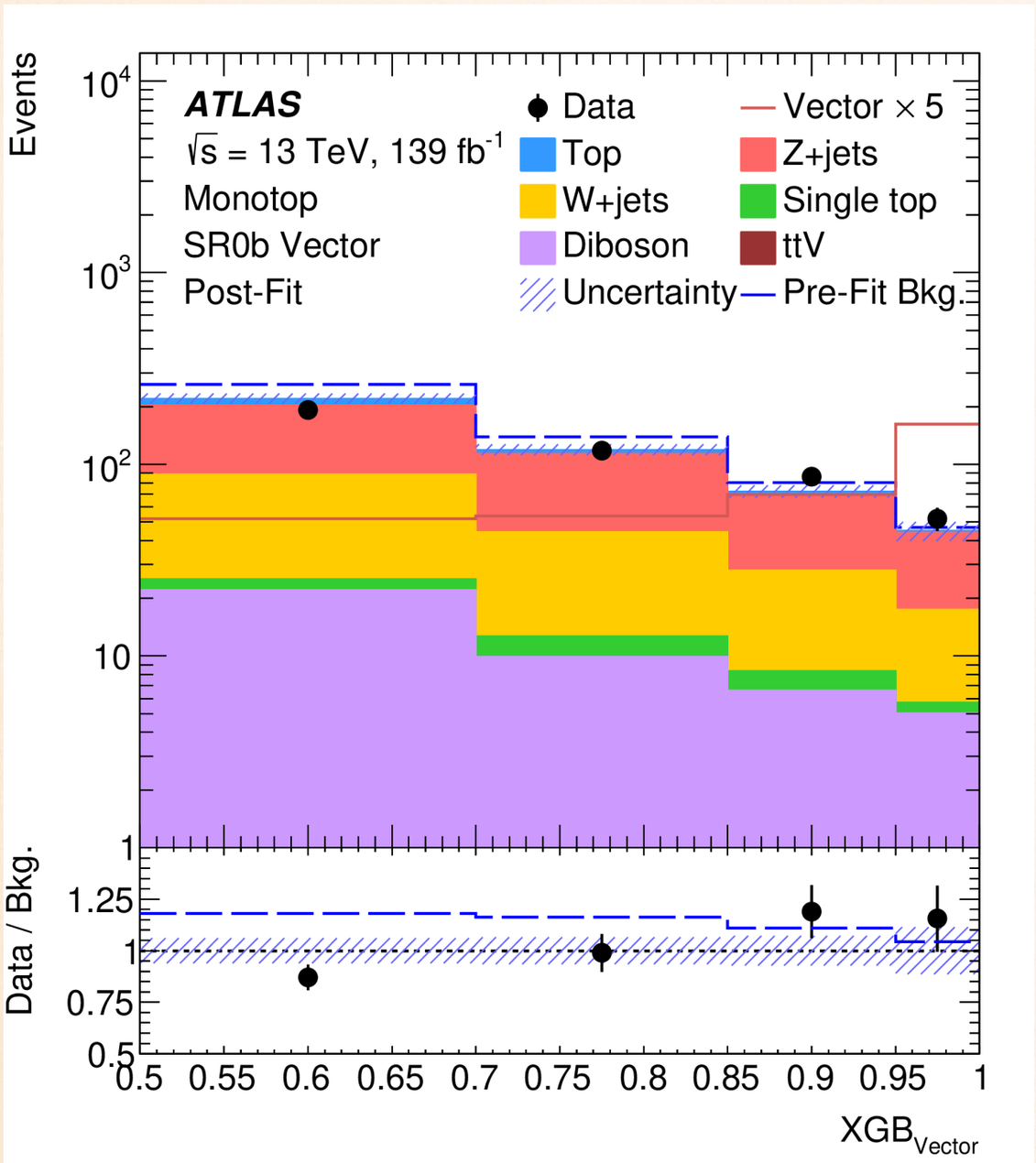
MONOTOP SIGNAL REGIONS DISTRIBUTIONS (SCALAR BDT)

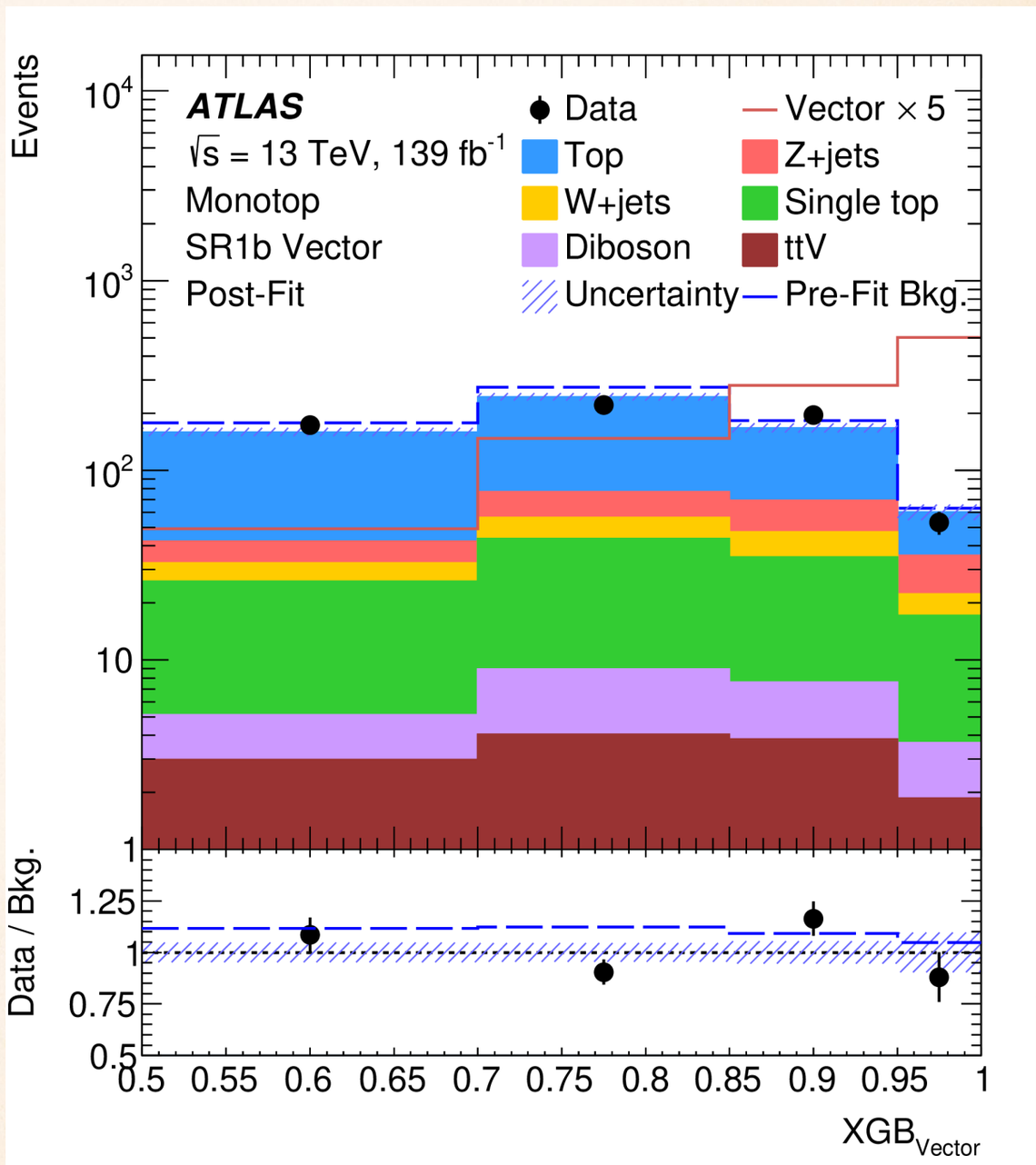




arXiv:2402.16561

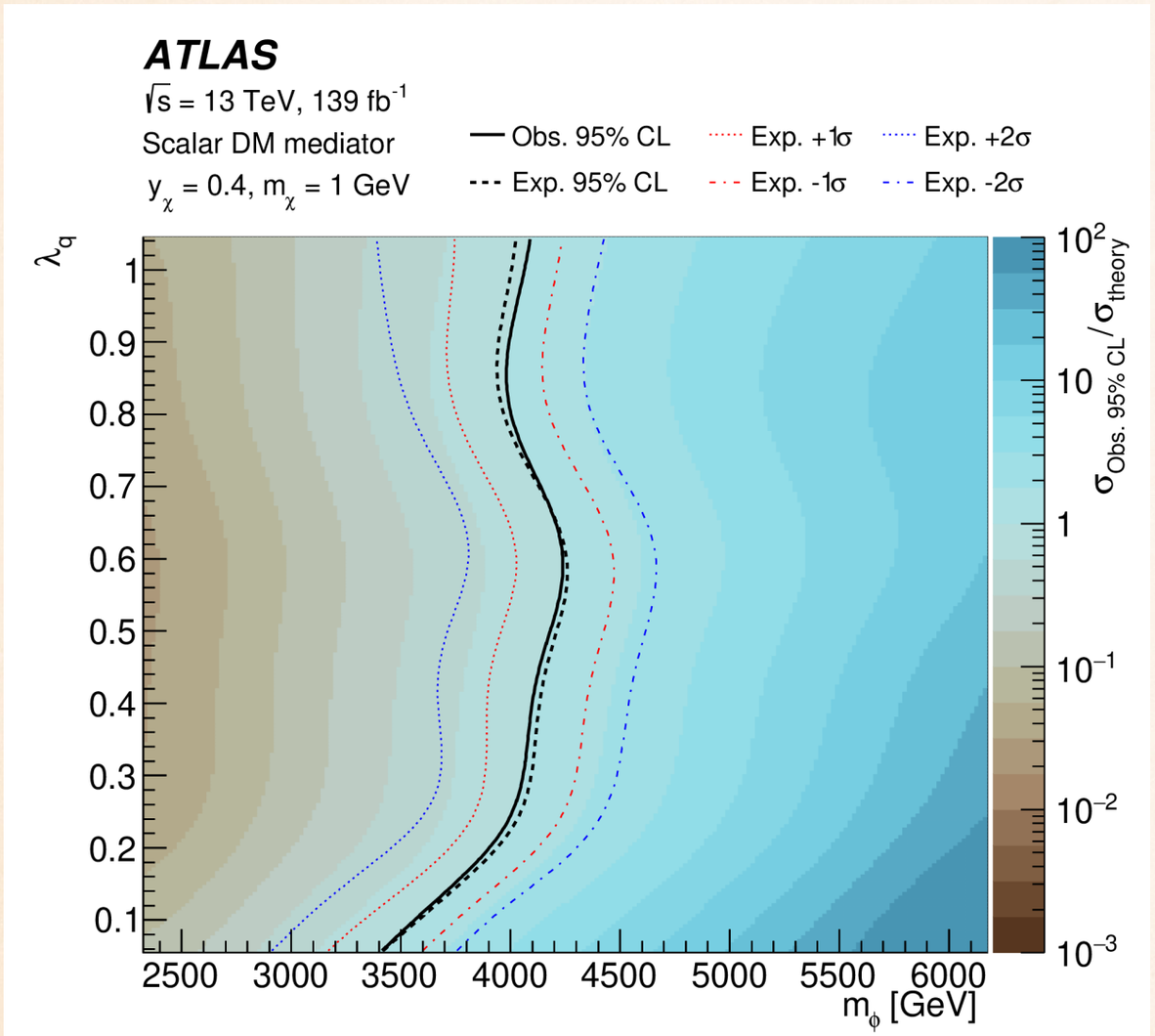
MONOTOP SIGNAL REGIONS DISTRIBUTIONS (VECTOR BDT)

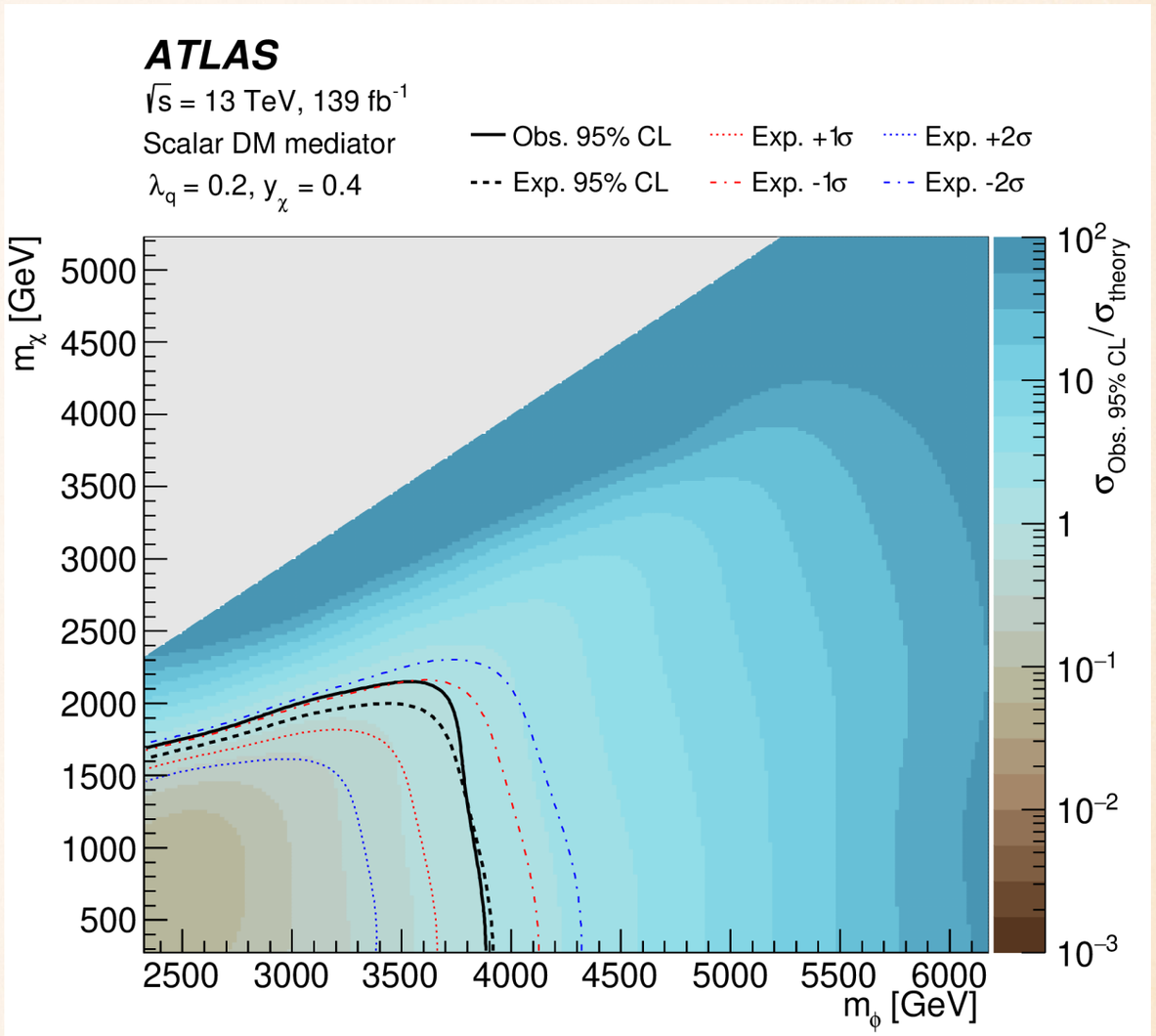




arXiv:2402.16561

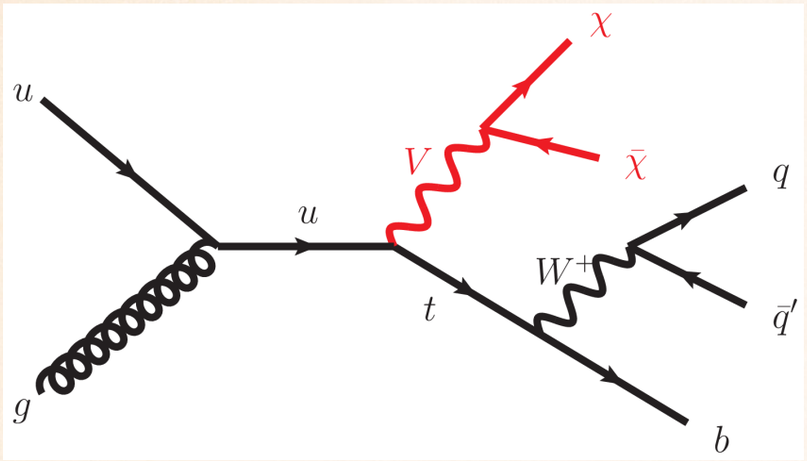
MONOTOP INTERPRETATIONS

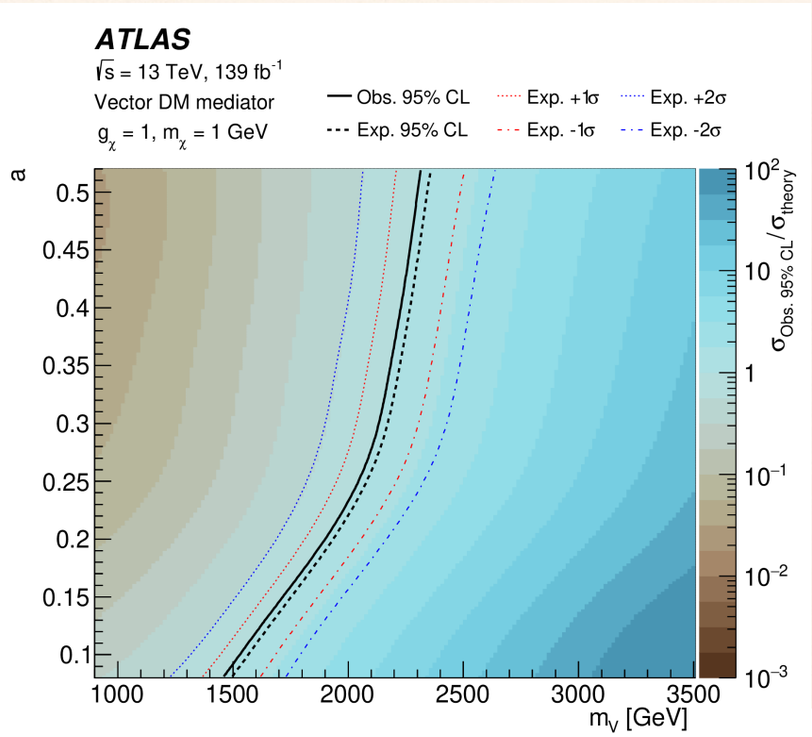


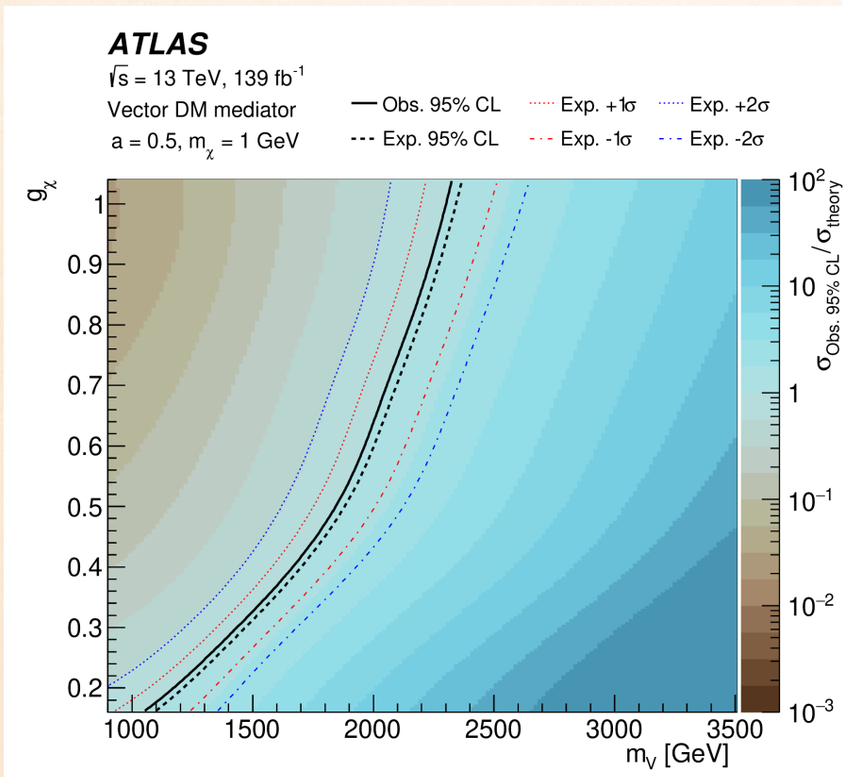


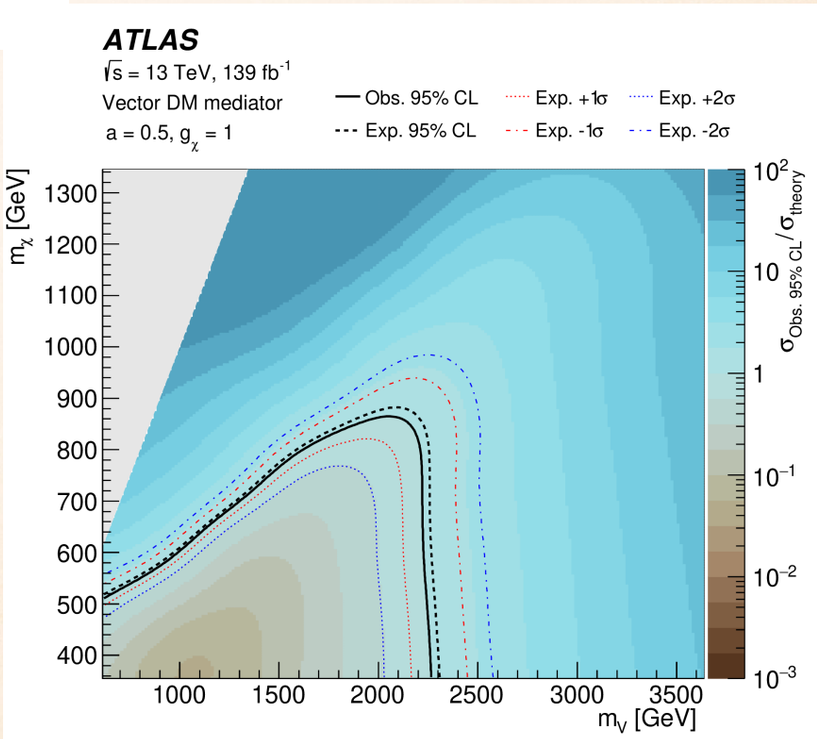
arXiv:2402.16561

MONOTOP VECTOR LIMITS



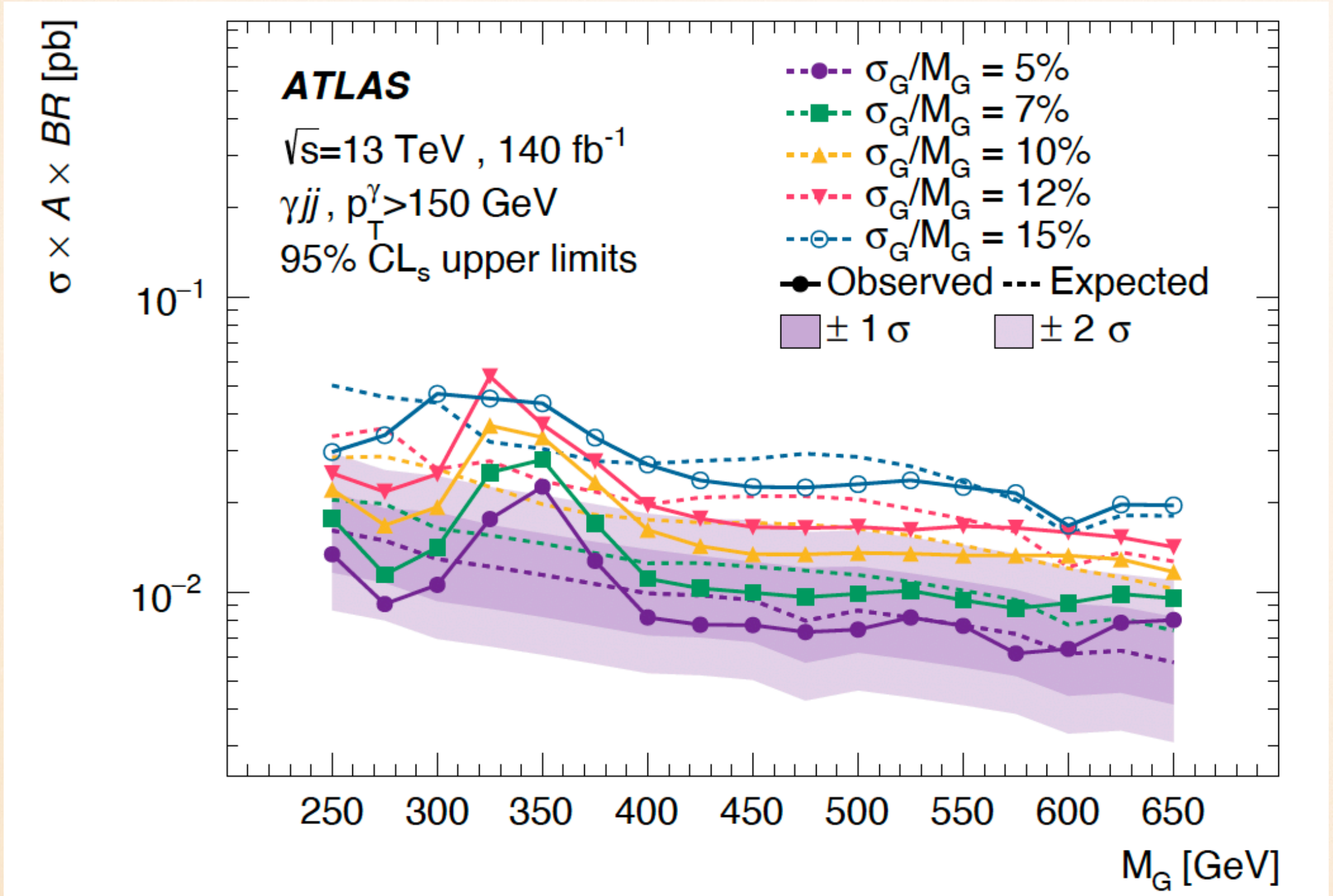






arXiv:2403.08547

ATLAS DIJET MODEL IND. LIMITS



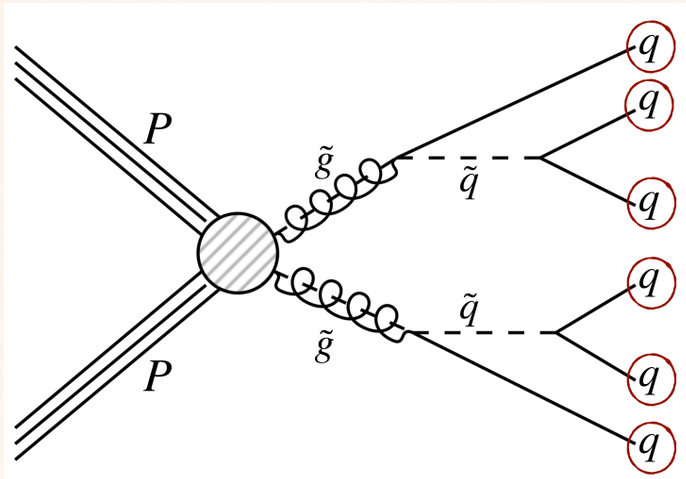
CMS-PAS-EXO-21-004

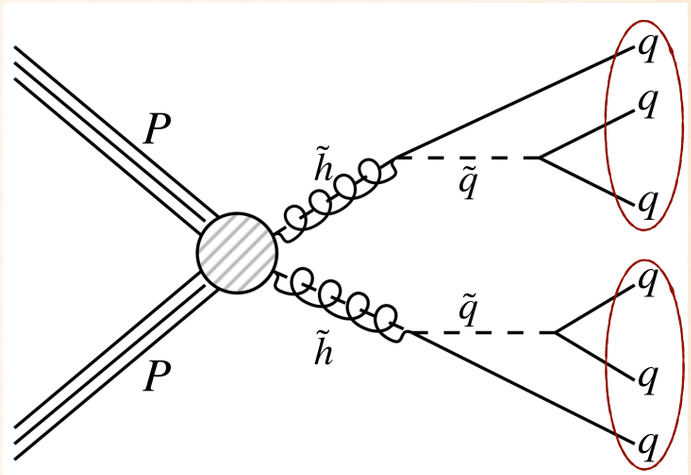
CMS JET RESONANCE SEARCH

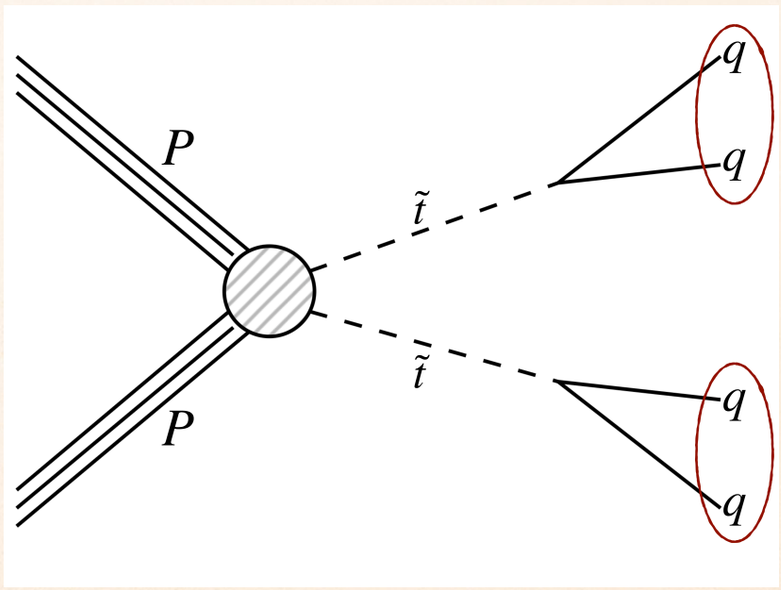
- Data scouting : events saved with trigger objects only to allow much higher rates

- Looking for resonance in boosted jet mass (2j, 3J channels) and resolved tri-jet mass.

- Interpreted for RPV gluino, squark, higgsino decays

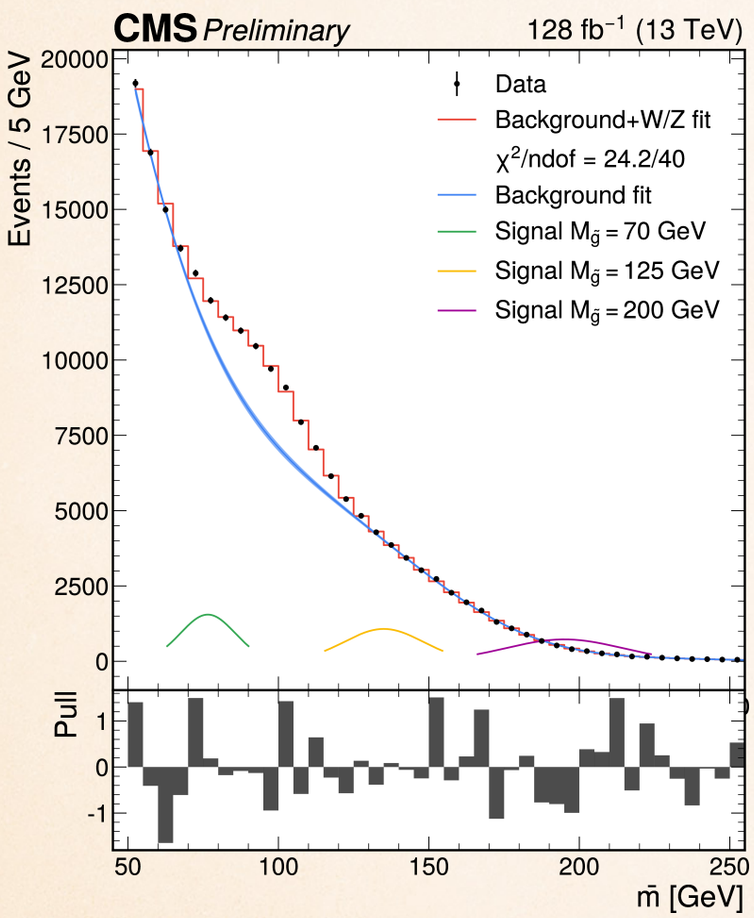




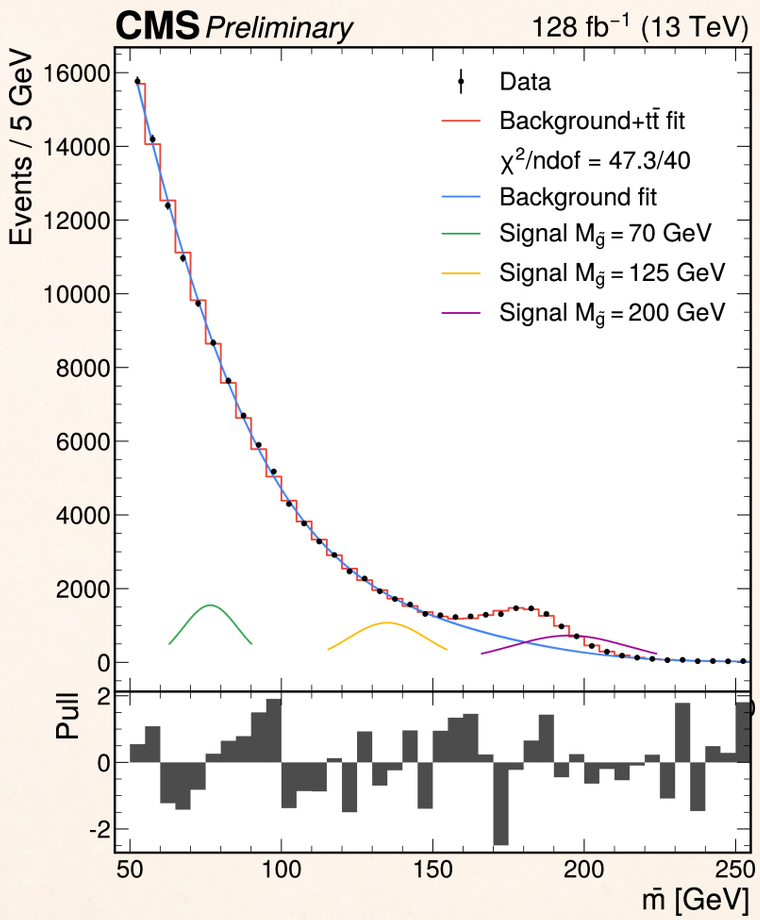


CMS-PAS-EXO-21-004

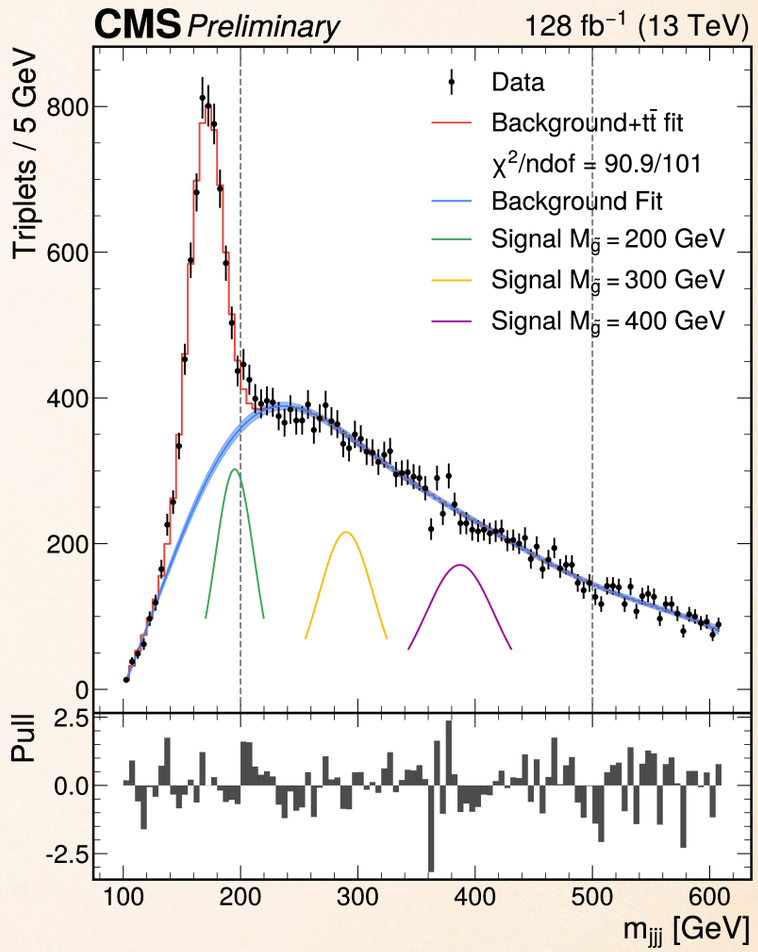
CMS JET RESONANCE SEARCH



2 jet boosted



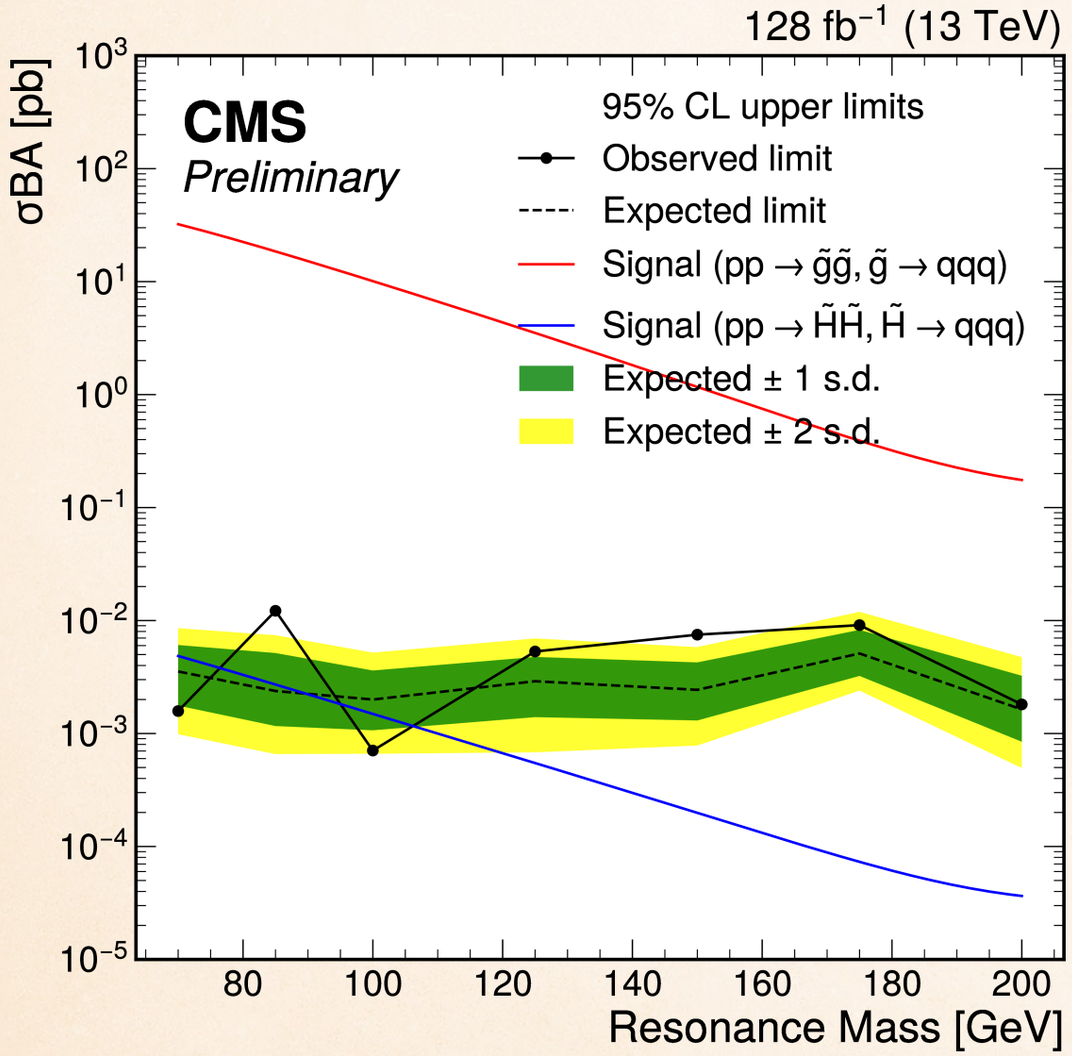
3 jets boosted



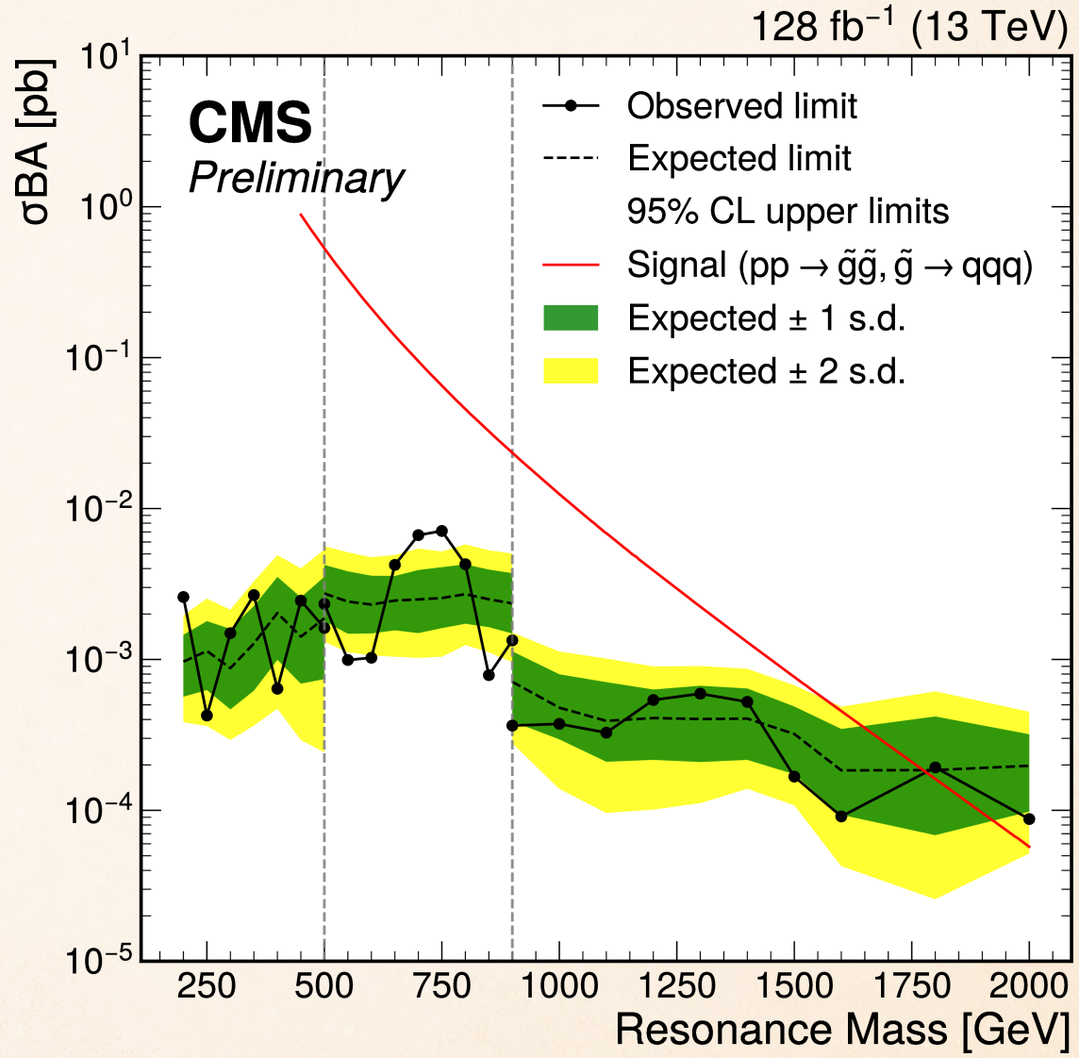
3 jet resolved

CMS-PAS-EXO-21-004

CMS JET RESONANCE SEARCH

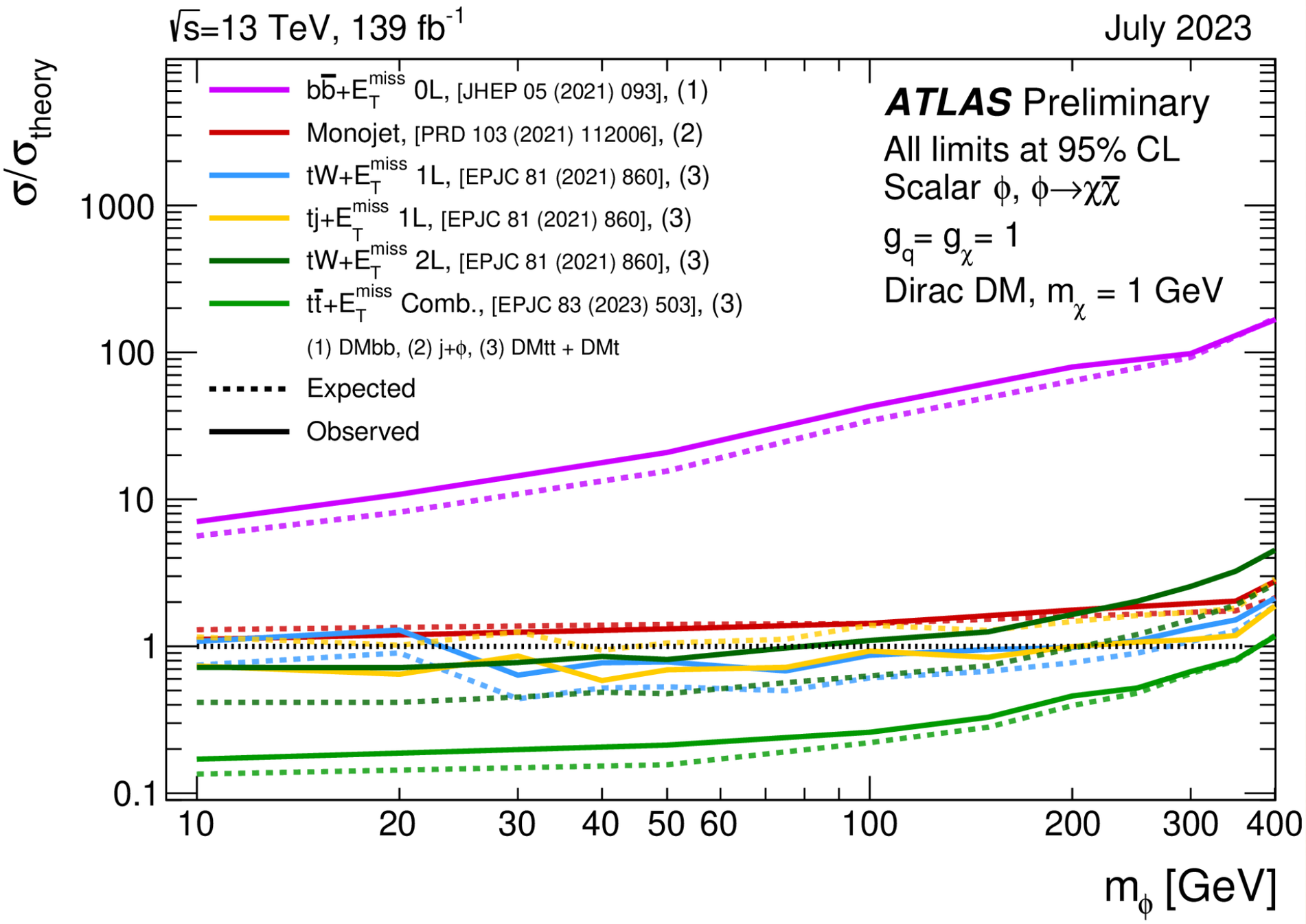


3 jets boosted limits

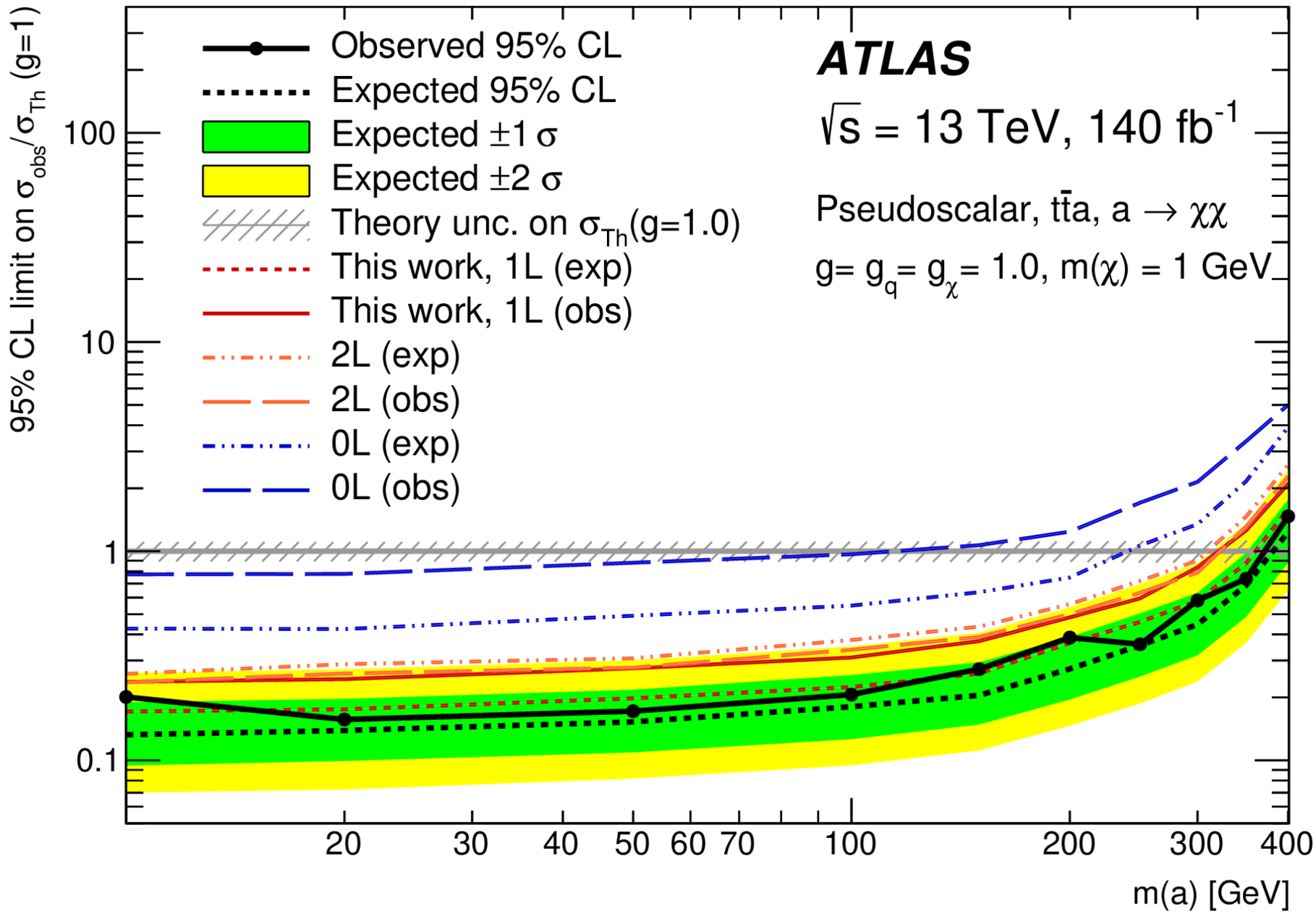


3 jets resolved limits

S-CHANNEL SCALAR MEDIATOR



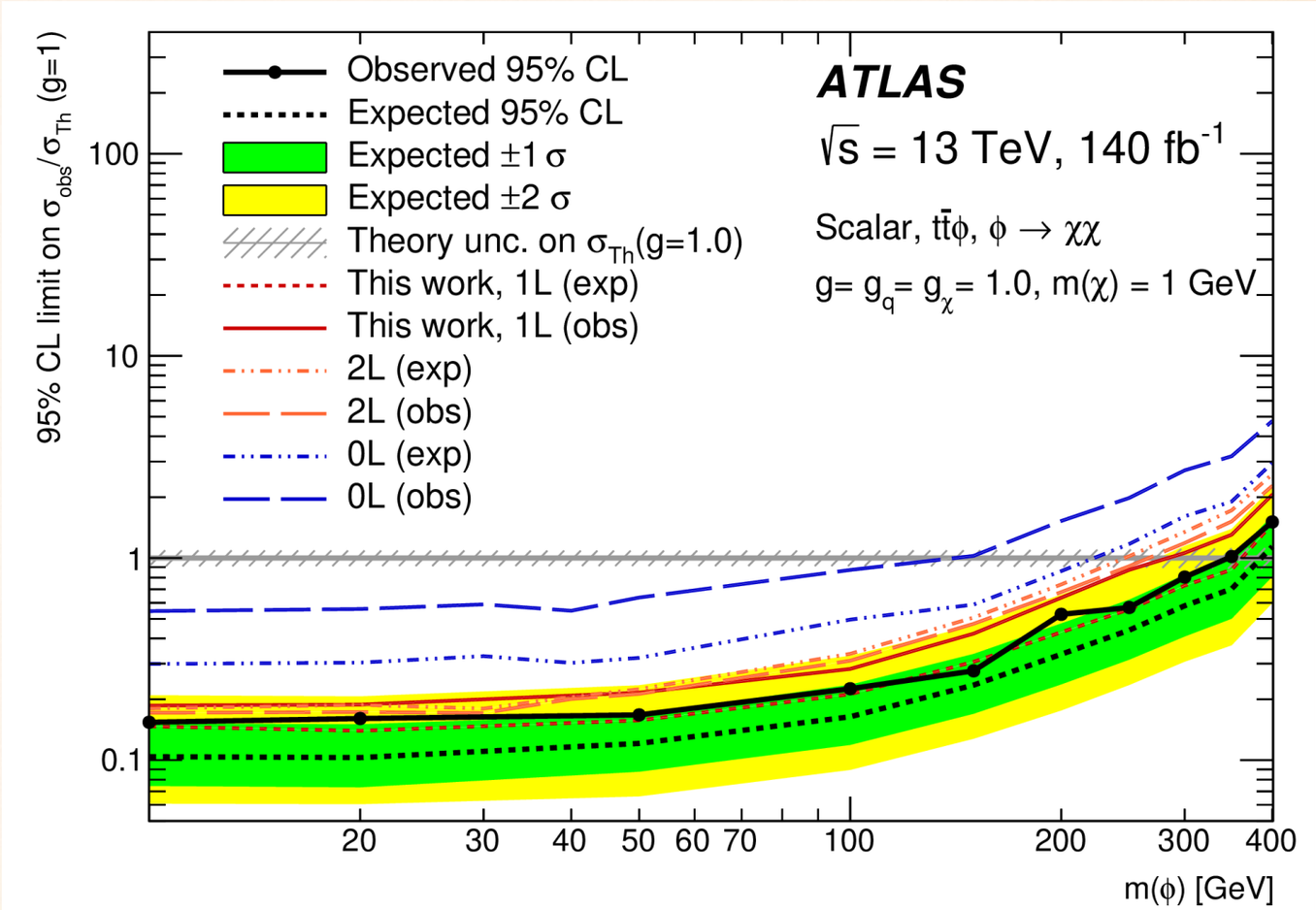
S-CHANNEL PSEUDOSCALAR MEDIATOR



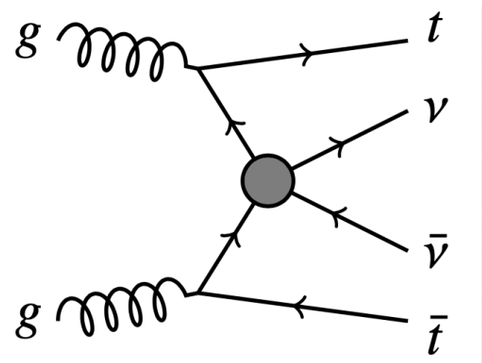
arXiv:2401.13430

DM ATLAS ~~STOP~~ 1L

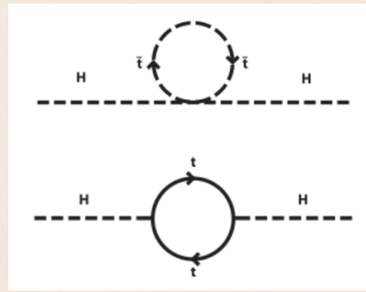
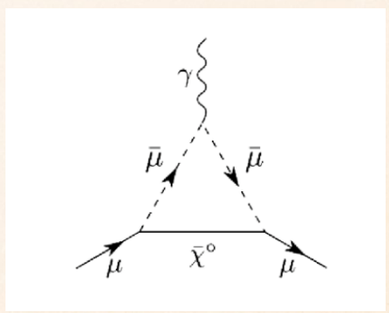
- 2nd ATLAS paper with full DM run 2 dataset targeting ~~stop~~ ~~pair~~ production in 1 lepton channel
- Neural Networks to reconstruct top hadronic decays and S/B separation
- Optimization for smaller $\Delta m(\tilde{t},\tilde{\chi})$
- Combination with 0L



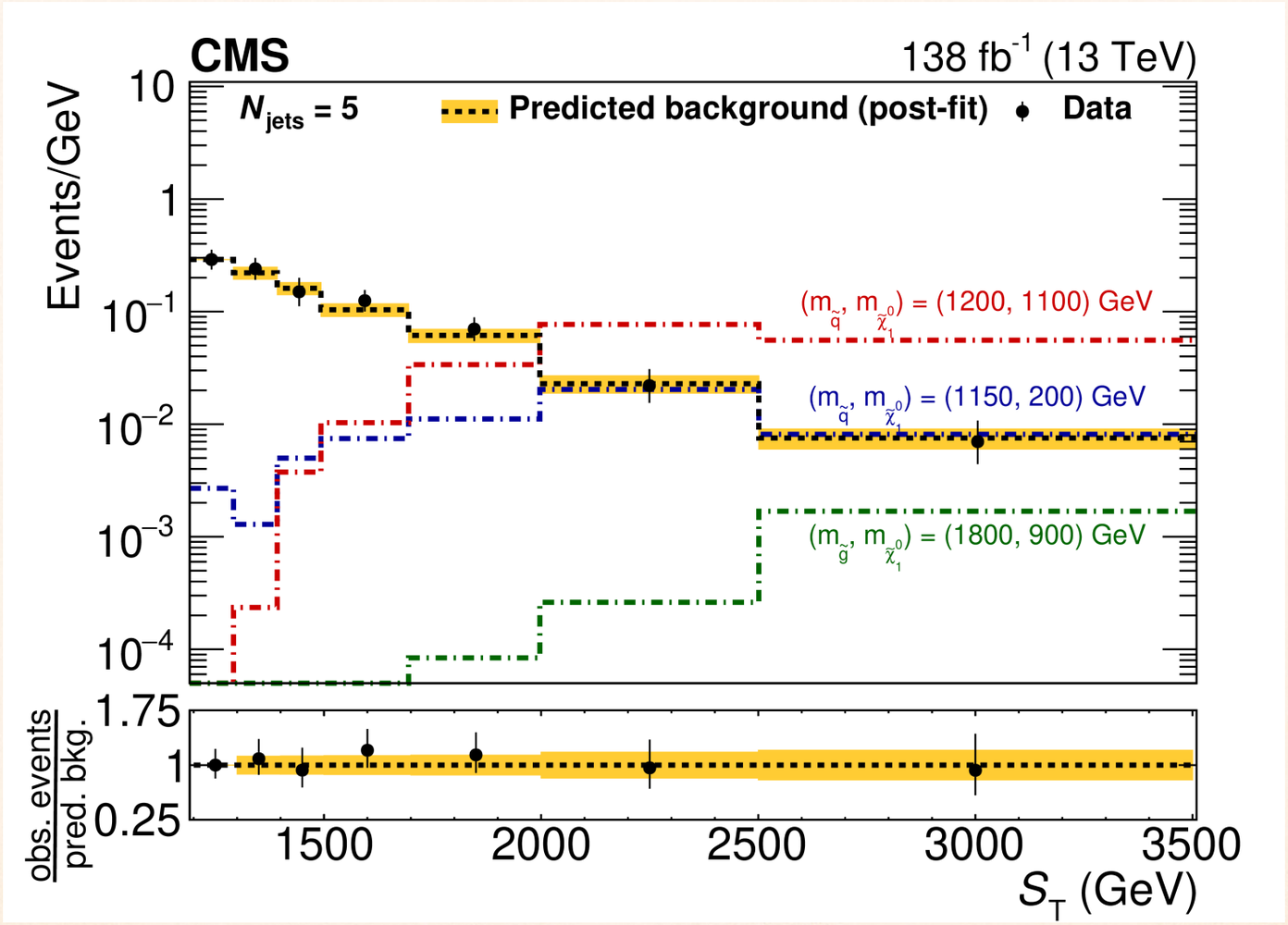
Pseudoscalar limits in backup



SUPERSYMMETRY

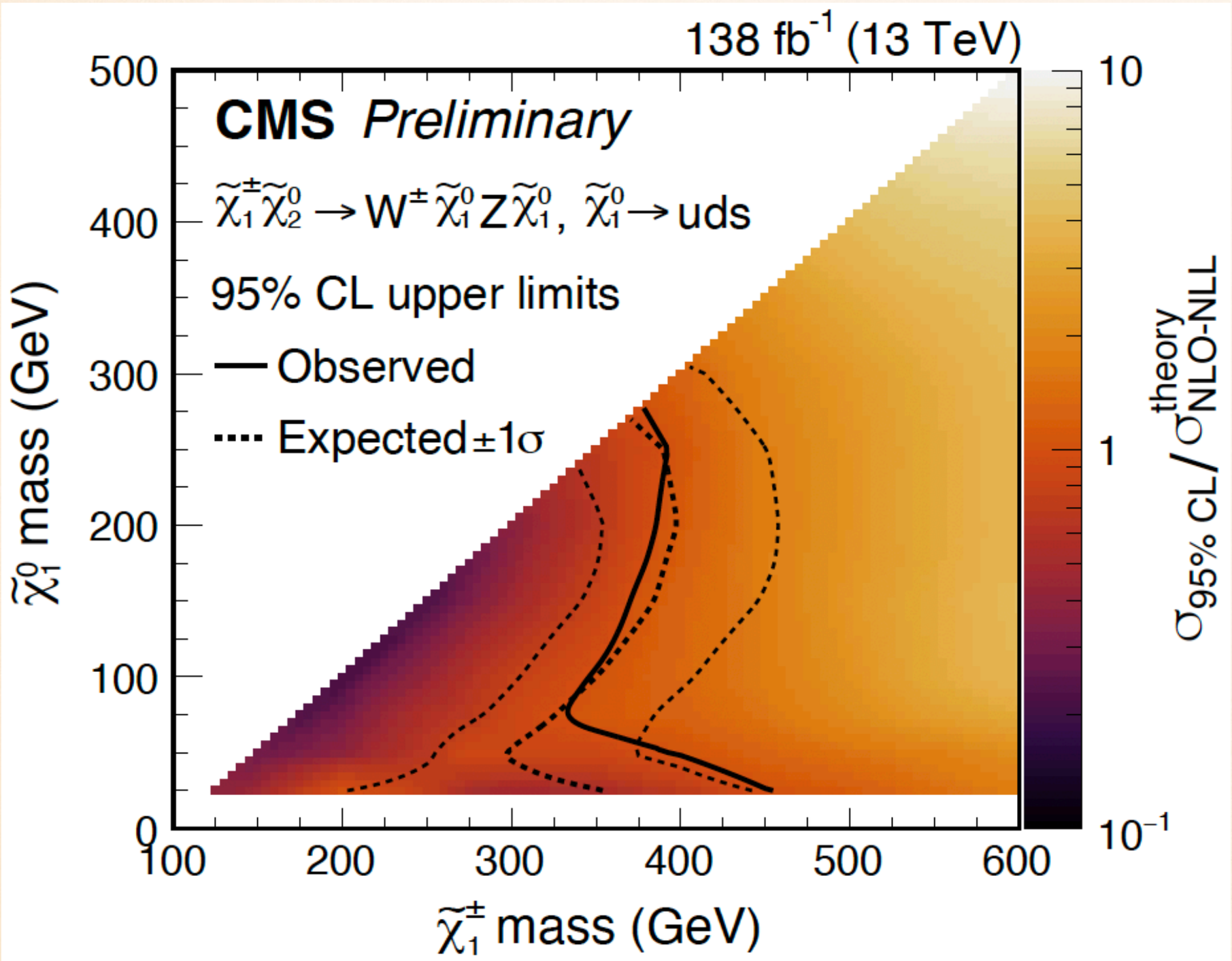
Dark Matter candidate	✓	$\tilde{\chi}_1^0$
EWK scale naturalness	✓	
Explanation for muon g-2	✓	
Observed at LHC	✗	

CMS STEALTH SUSY

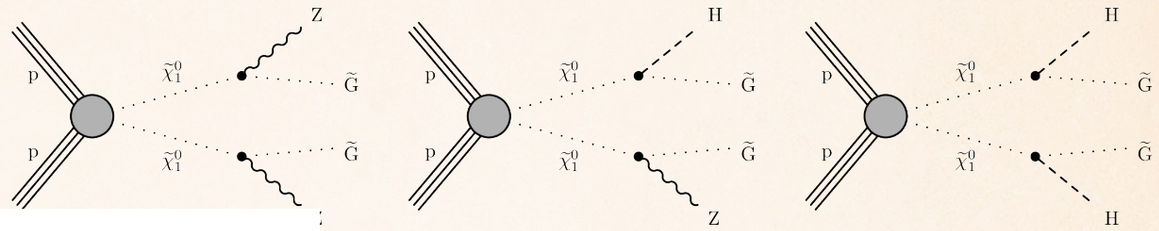


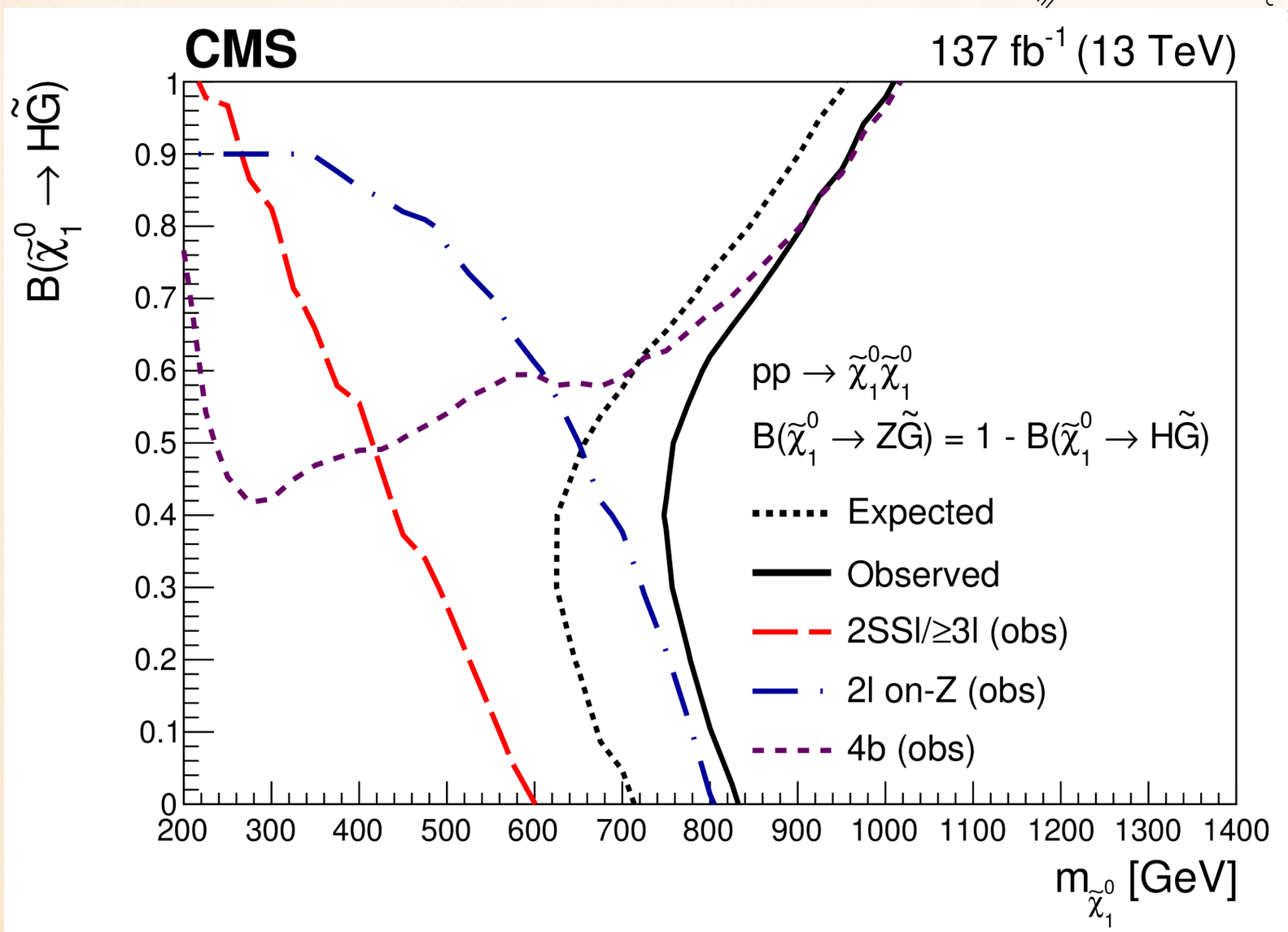
Background from S_T template in bins of Njets, estimated from Njets=2 data plus MC corrections

CMS RPV NEW RESULT

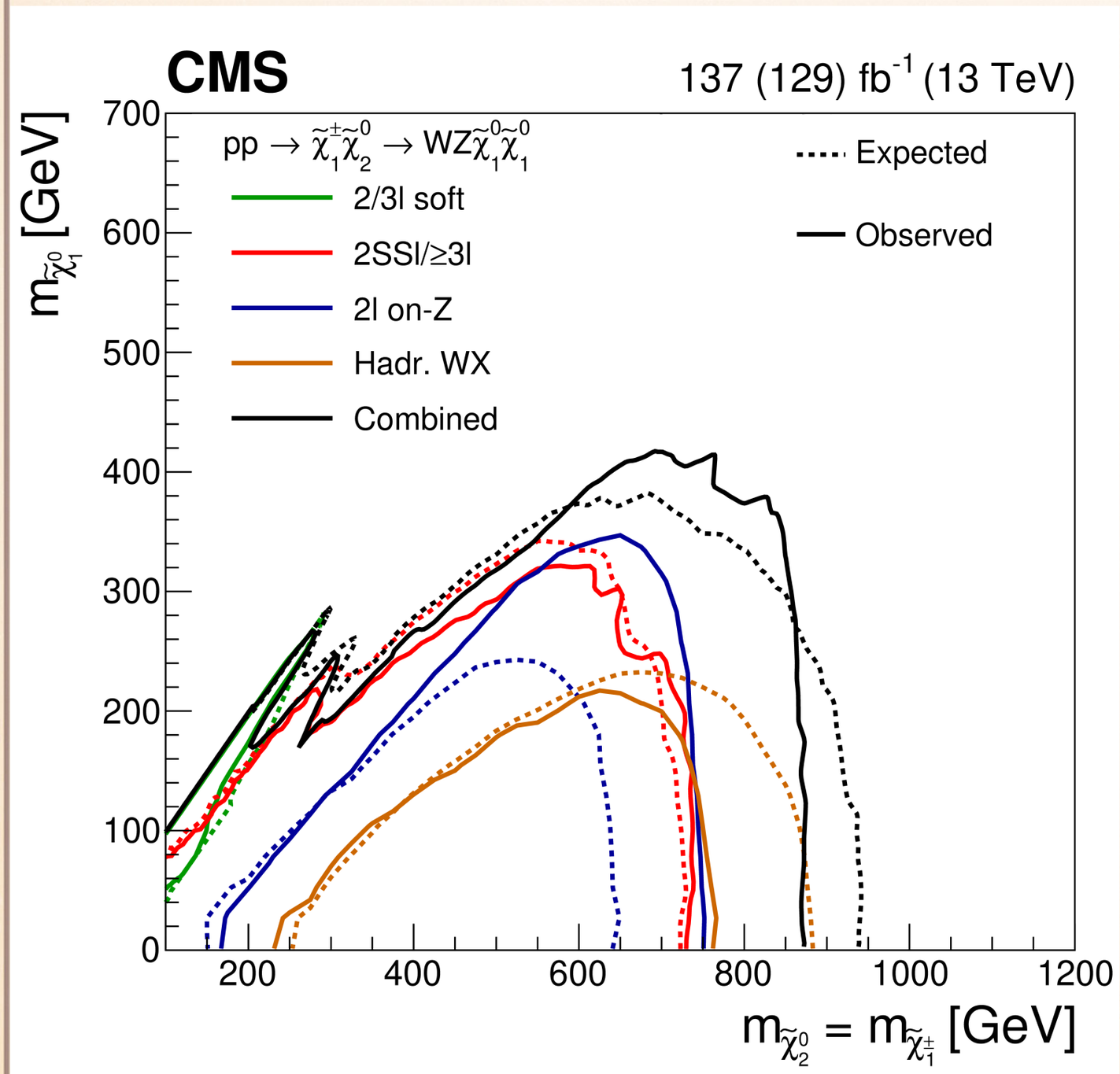


CMS GMSB

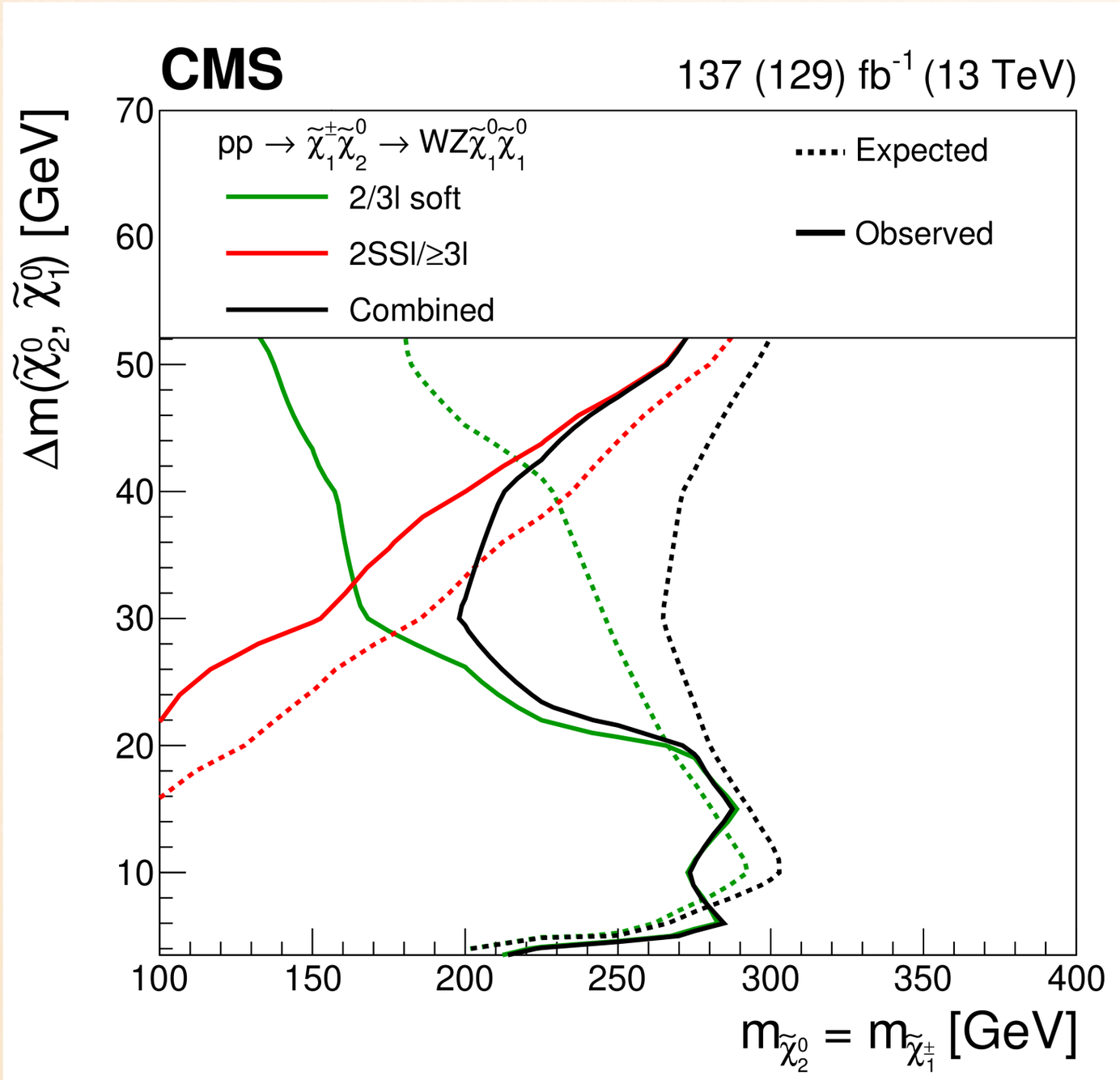

p
p
$\tilde{\chi}_1^0$
$\tilde{\chi}_1^0$
Z
H
$\tilde{G}$
$\tilde{G}$


CMS
137 fb^{-1} (13 TeV)
$B(\tilde{\chi}_1^0 \to H\tilde{G})$
$pp \to \tilde{\chi}_1^0\tilde{\chi}_1^0$
$B(\tilde{\chi}_1^0 \to Z\tilde{G}) = 1 - B(\tilde{\chi}_1^0 \to H\tilde{G})$
Expected
Observed
2SSl/≥3l (obs)
2l on-Z (obs)
4b (obs)
$m_{\tilde{\chi}_1^0}$ [GeV]

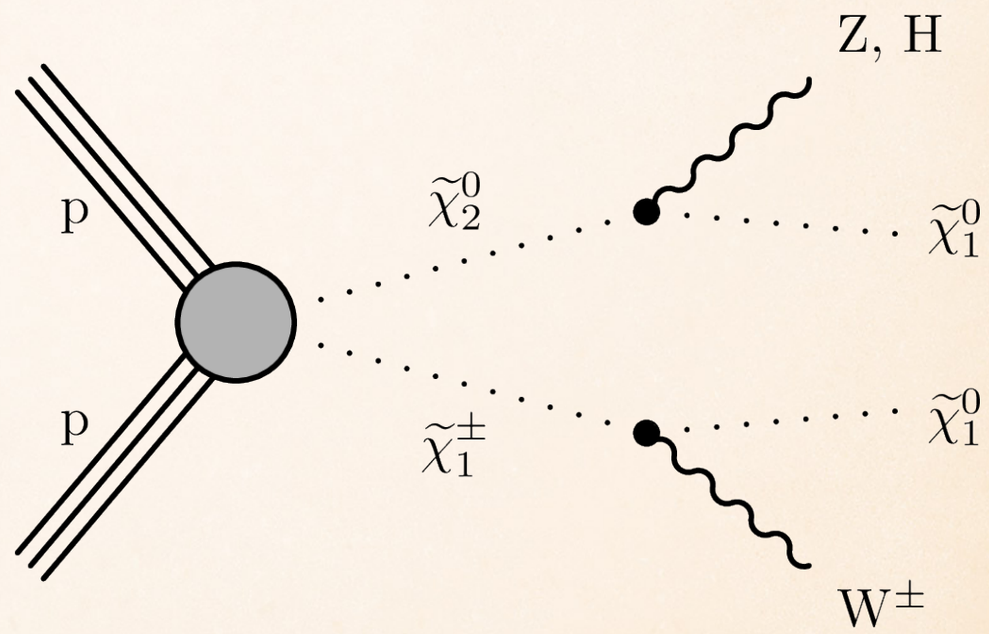
CMS WINO BINO ANALYSES



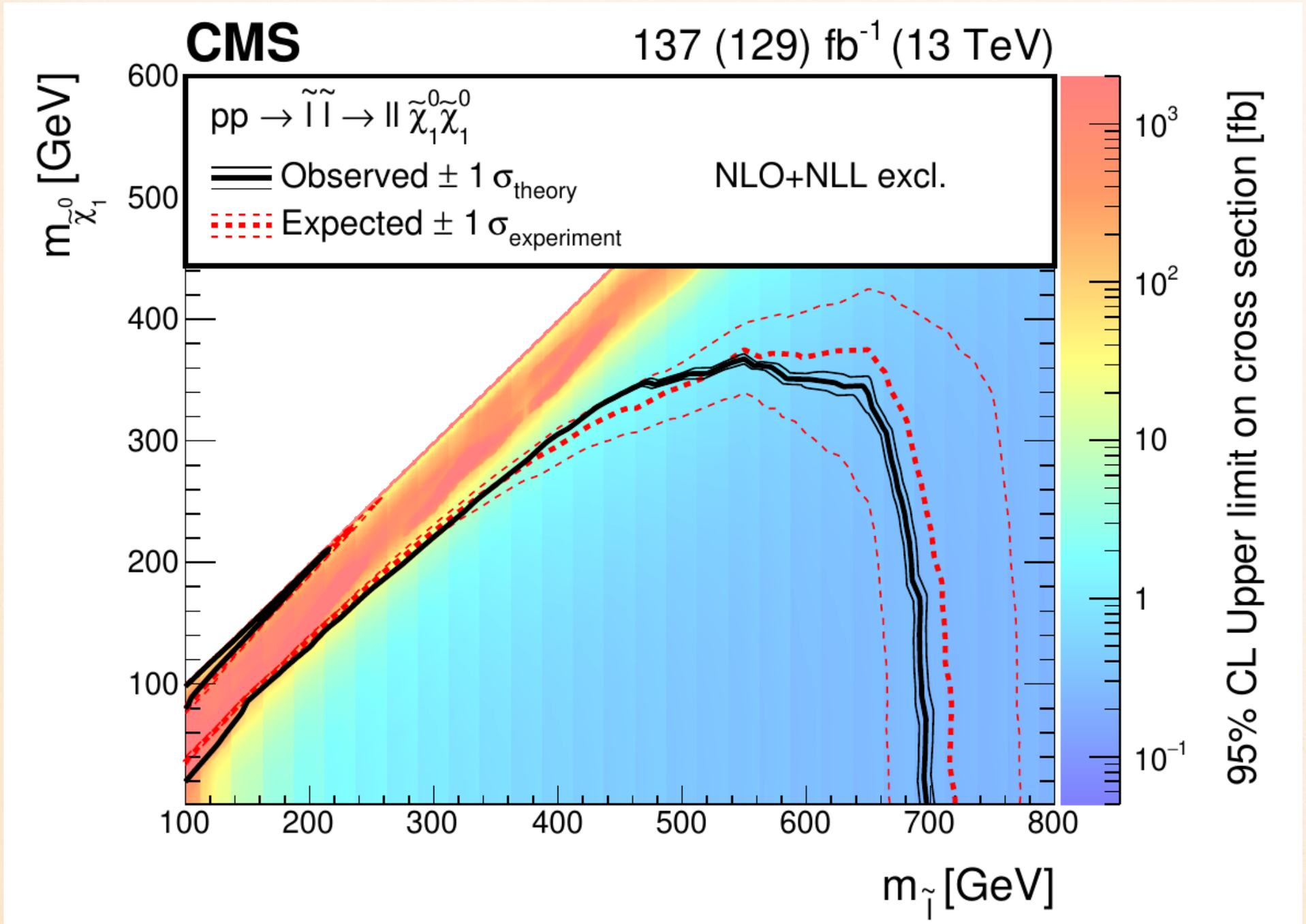
CMS COMPRESSED



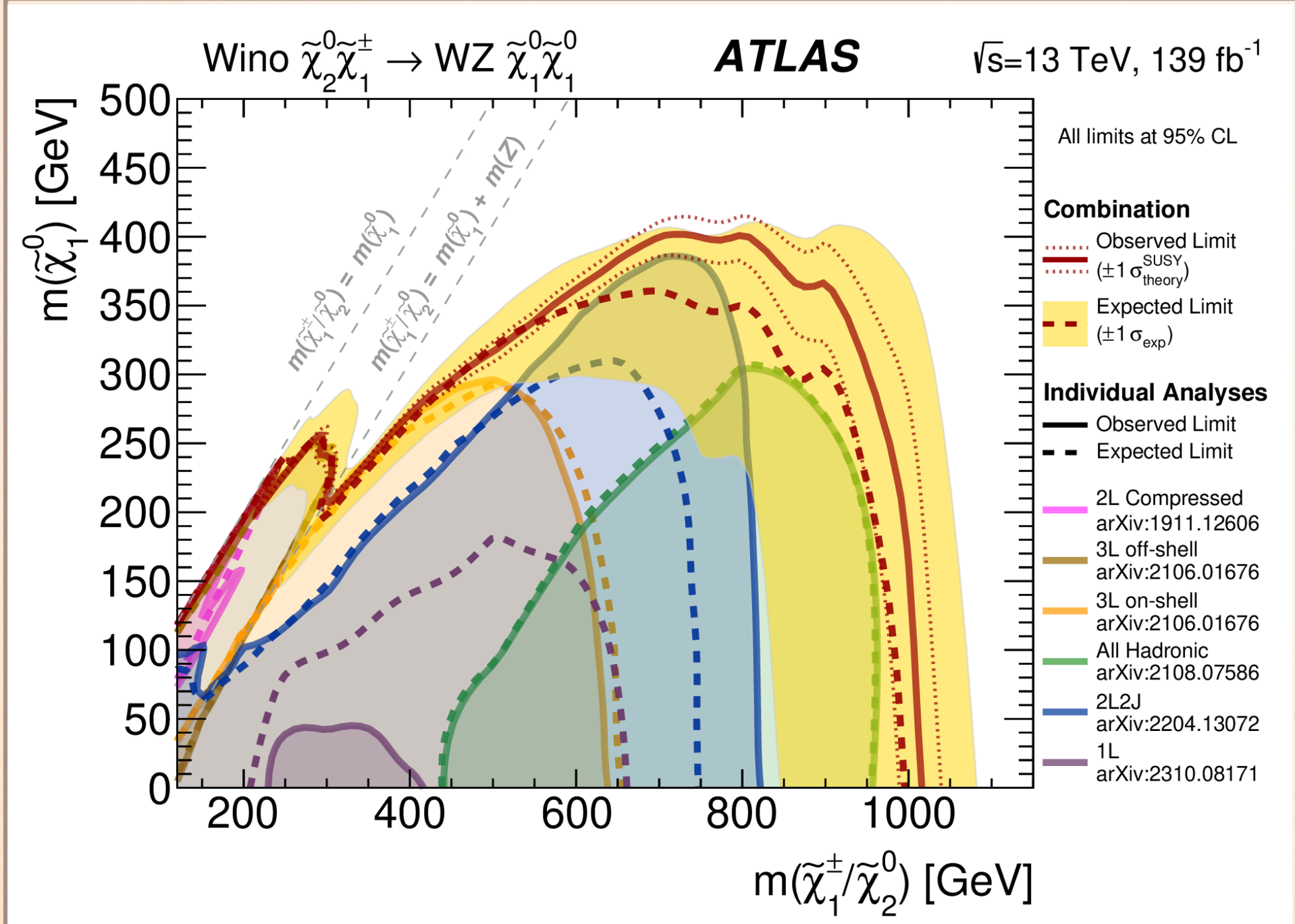
Wino NSLP, Bino LSP



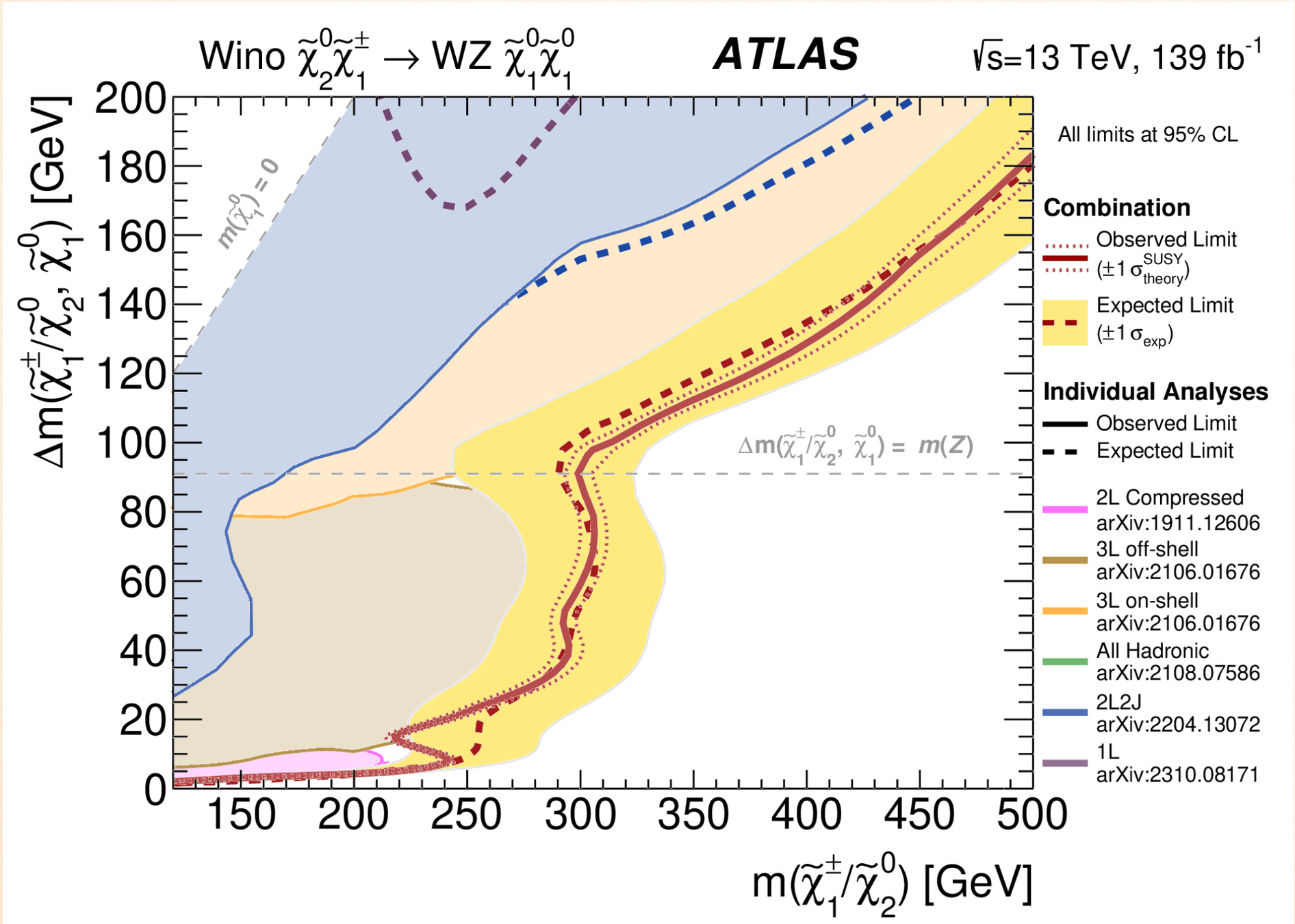
CMS SLEPTONS



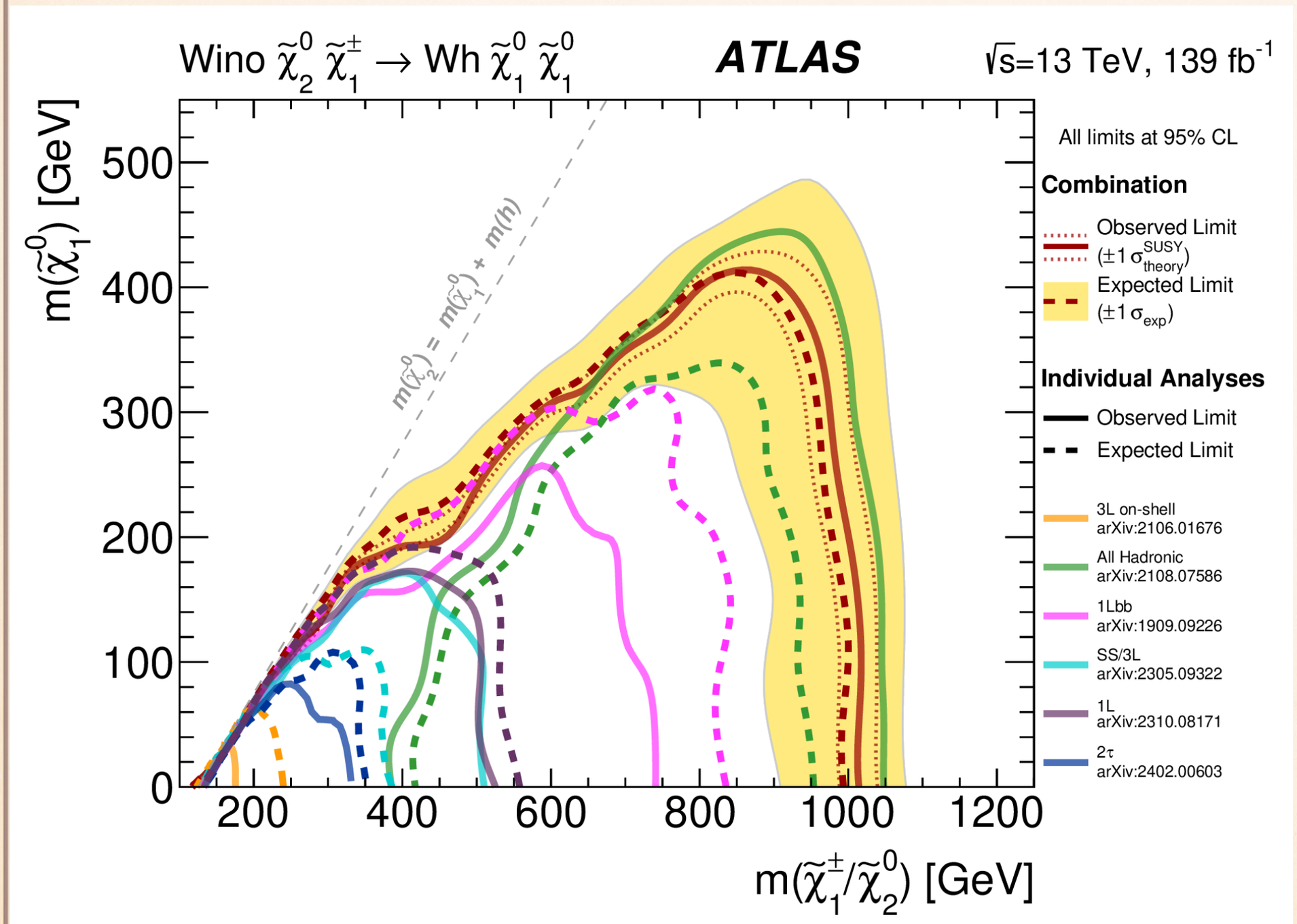
ATLAS WINO BINO (WZ MODEL)



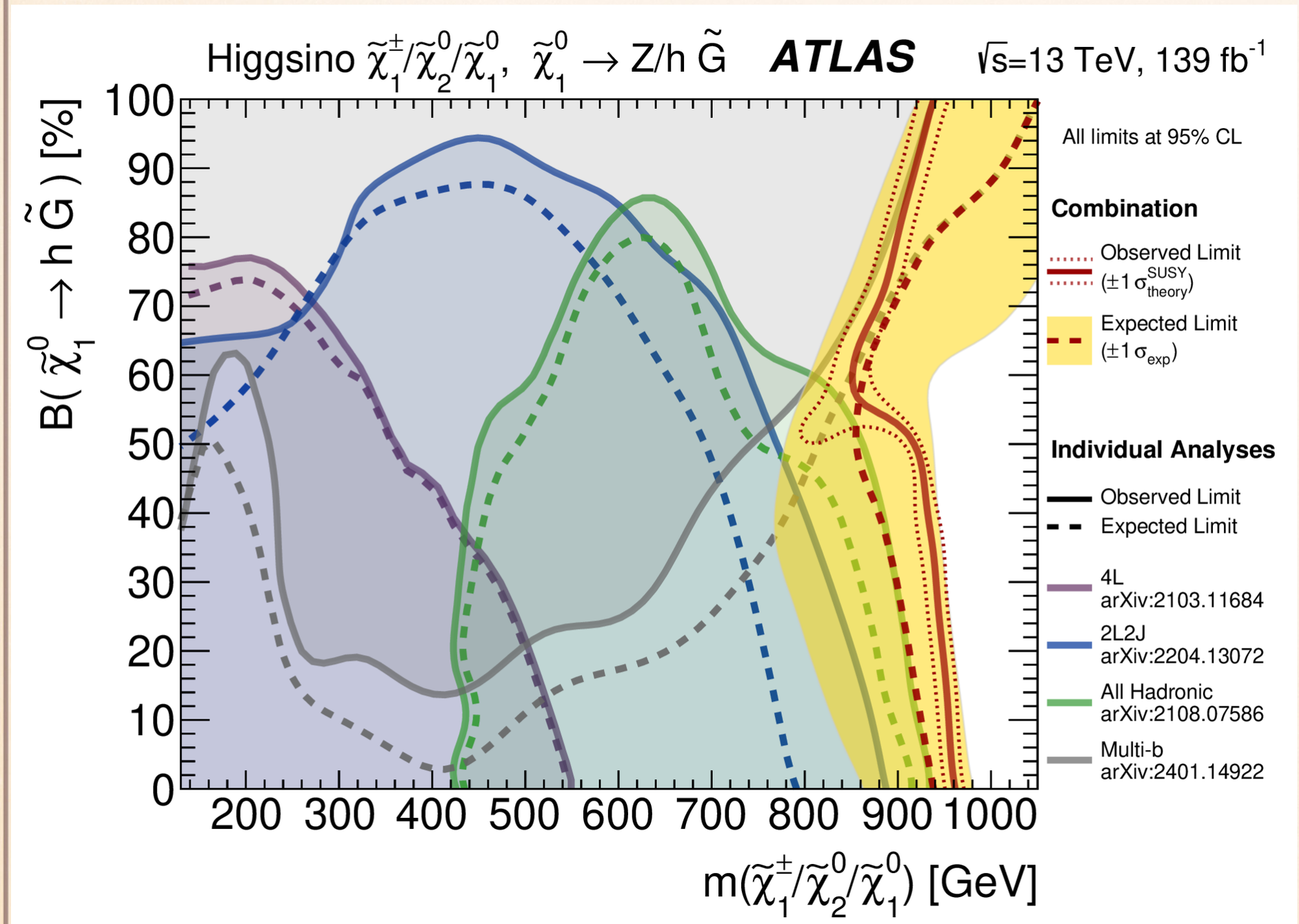
ATLAS WINO BINO (WZ MODEL)



ATLAS WINO BINO (WH MODEL)

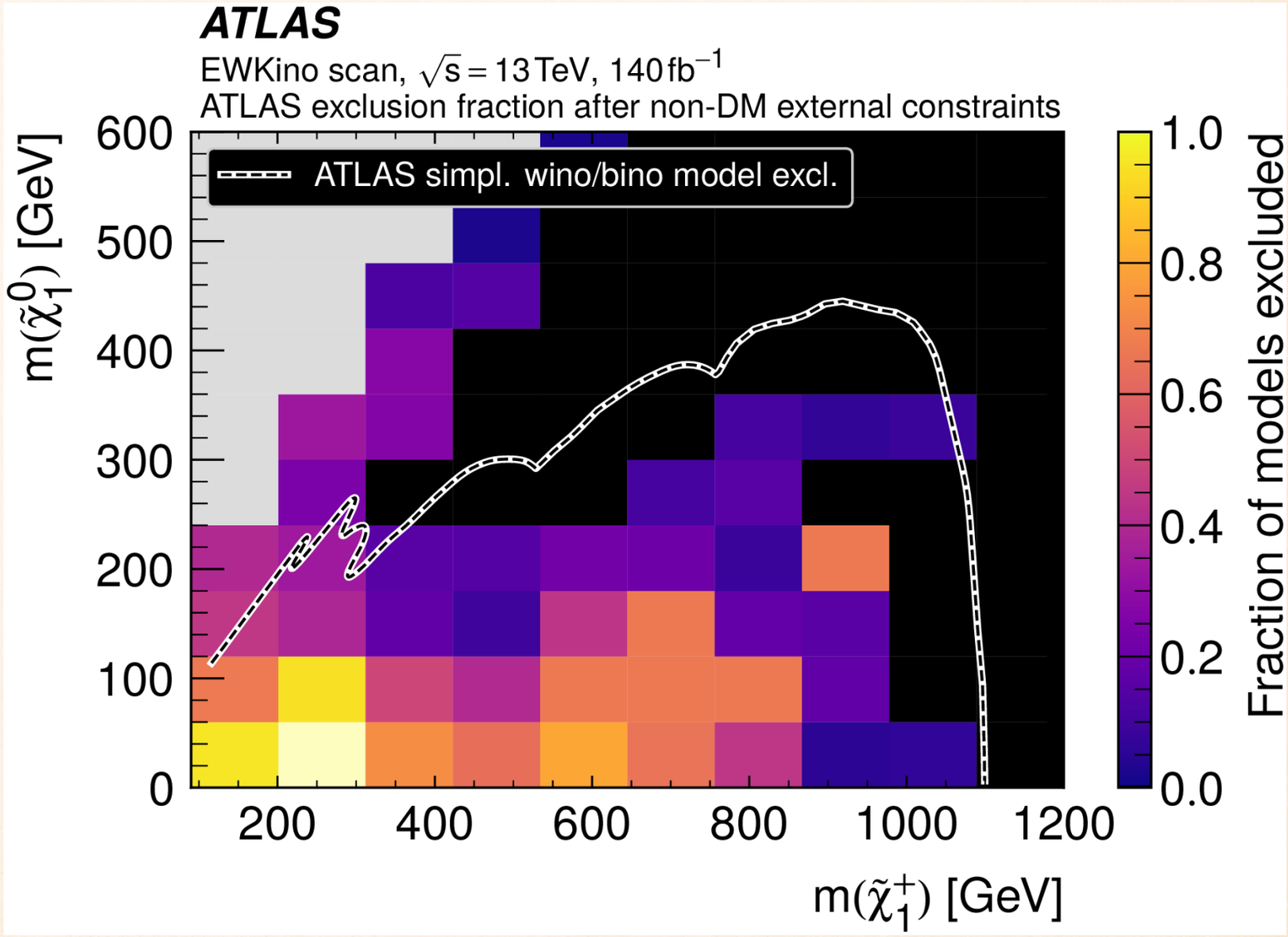


ATLAS HIGGSINO GRAVITINO



ELECTROWEAK PRODUCTION

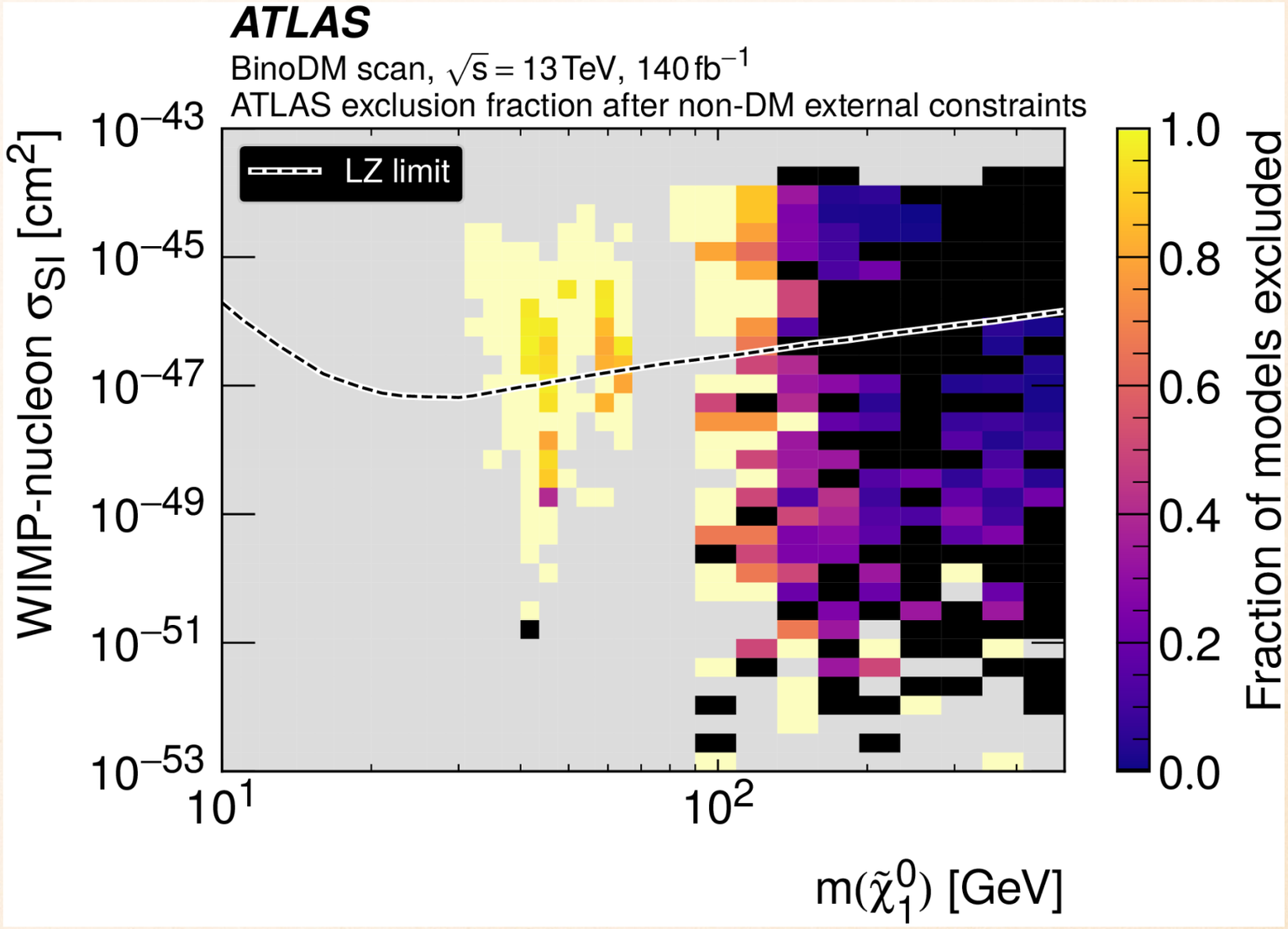
- Scan of the MSSM parameters
- Weaker limits than Simplified Models
- Good complementarity with direct production



arXiv:2402.08347

ELECTROWEAK PRODUCTION

Scan of the MSSM parameters shows weaker limits than Simplified Models and good complementarity with direct production



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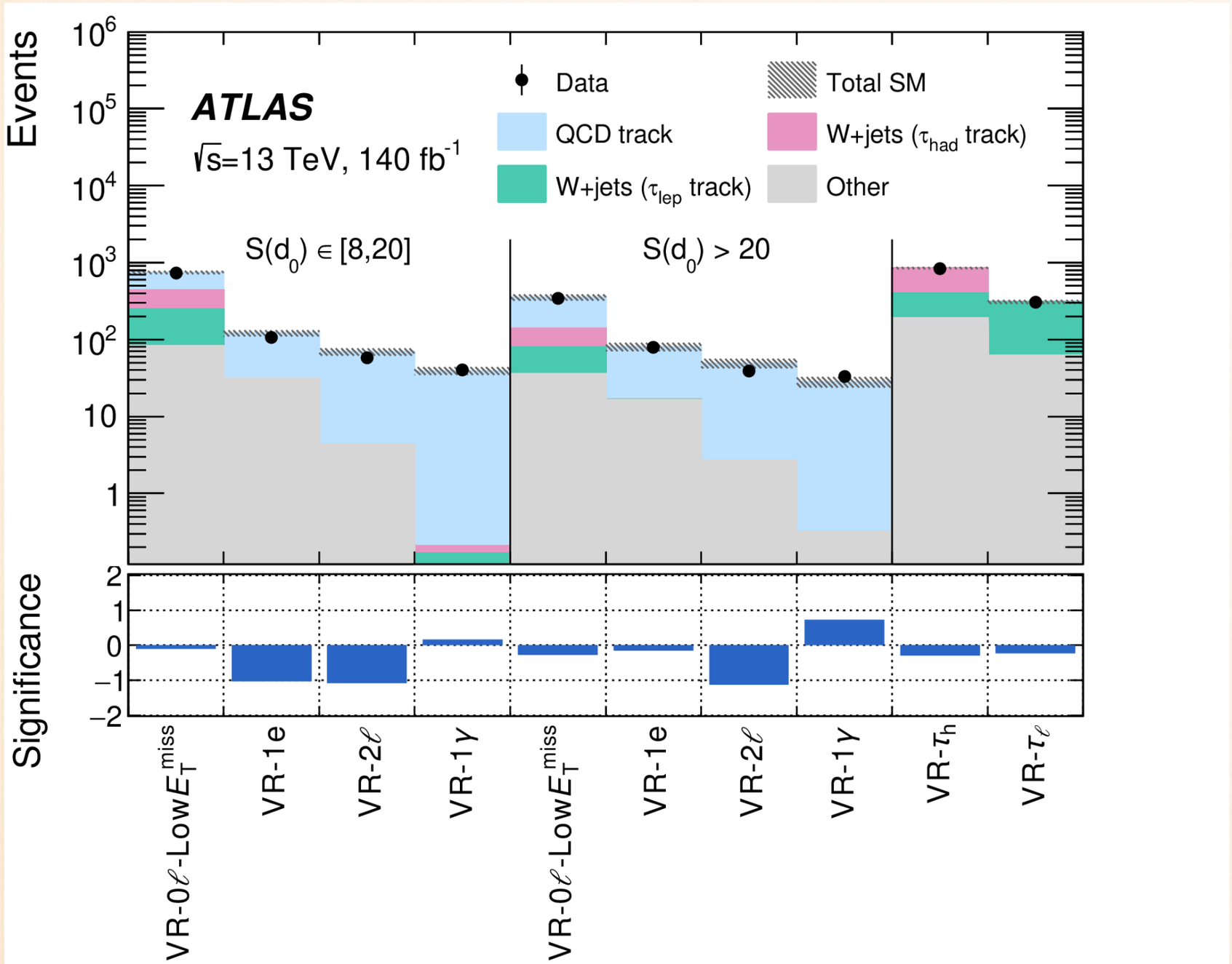
DISPLACED TRACK VALIDATION REGIONS



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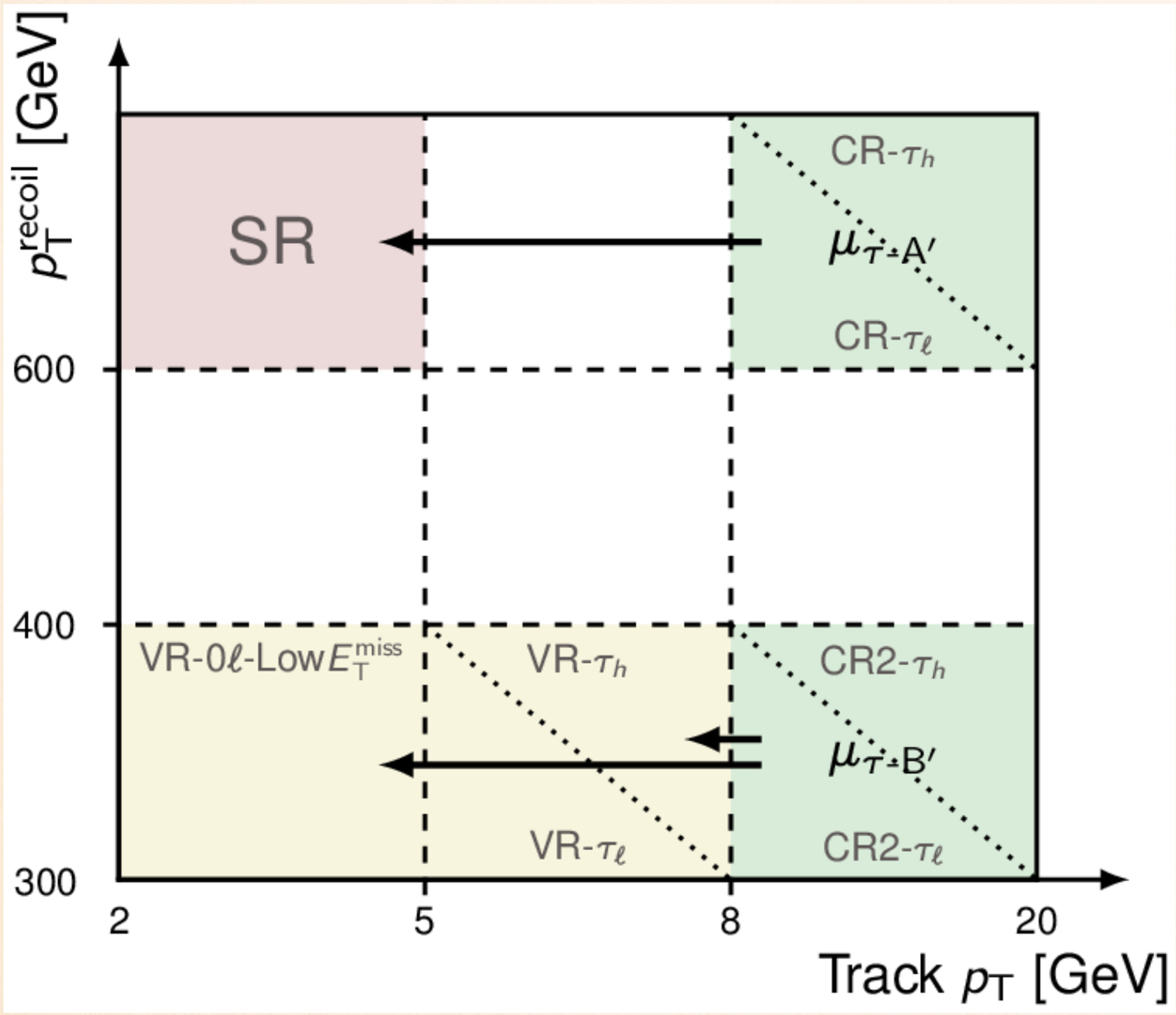
DISPLACED TRACK VALIDATION REGIONS



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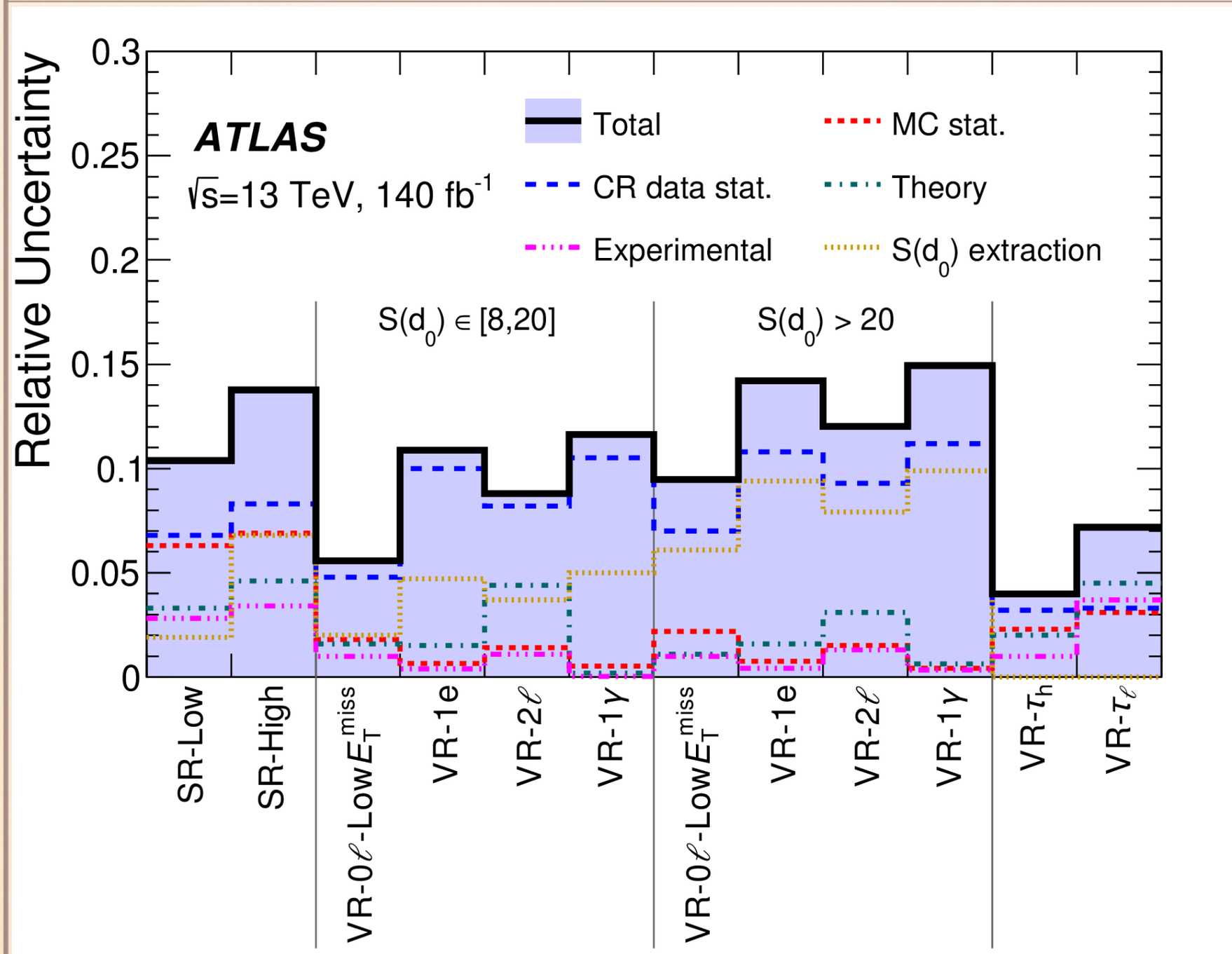
DISPLACED TRACK SYSTEMATICS



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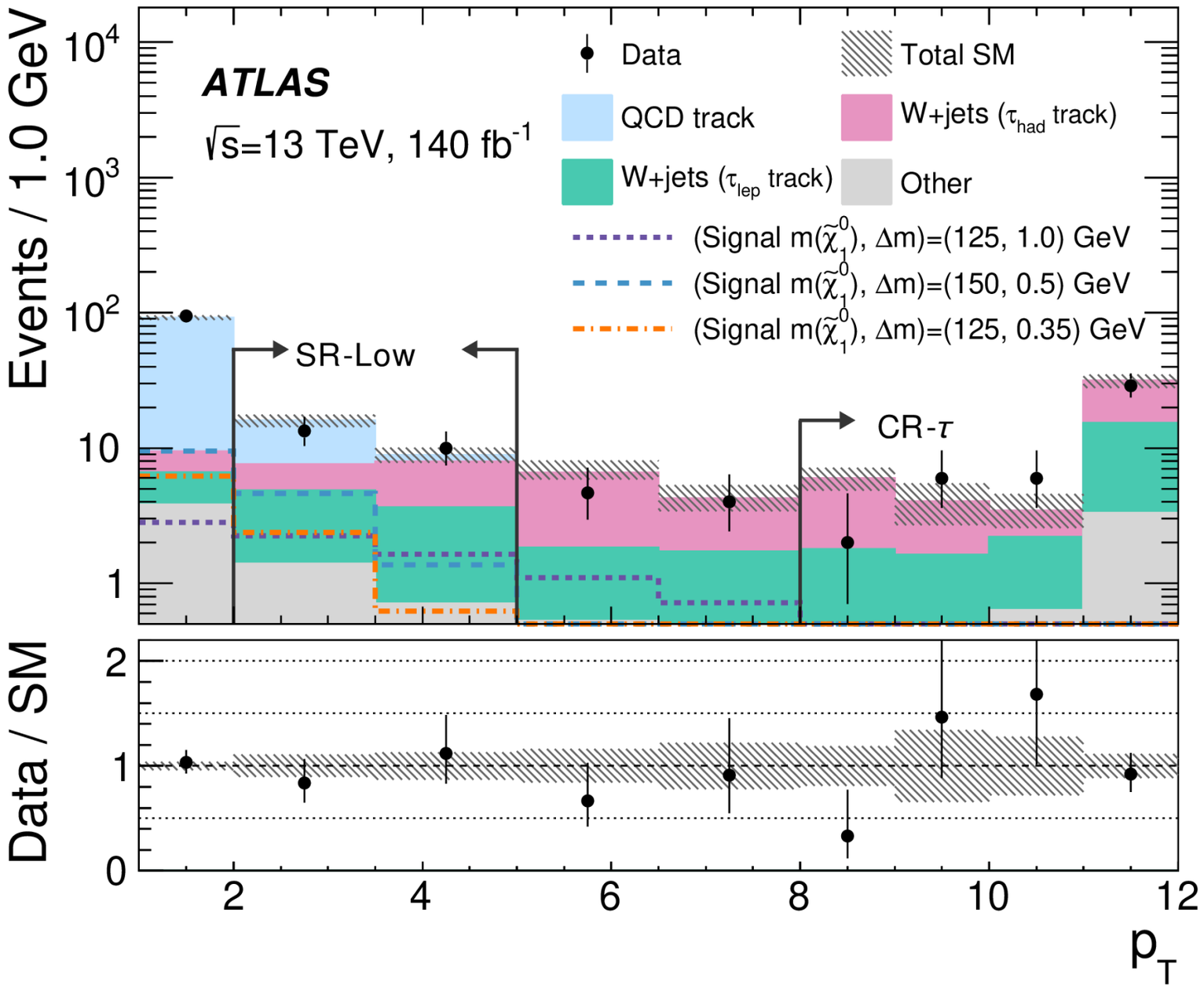
DISPLACED TRACK SR PT TRACK



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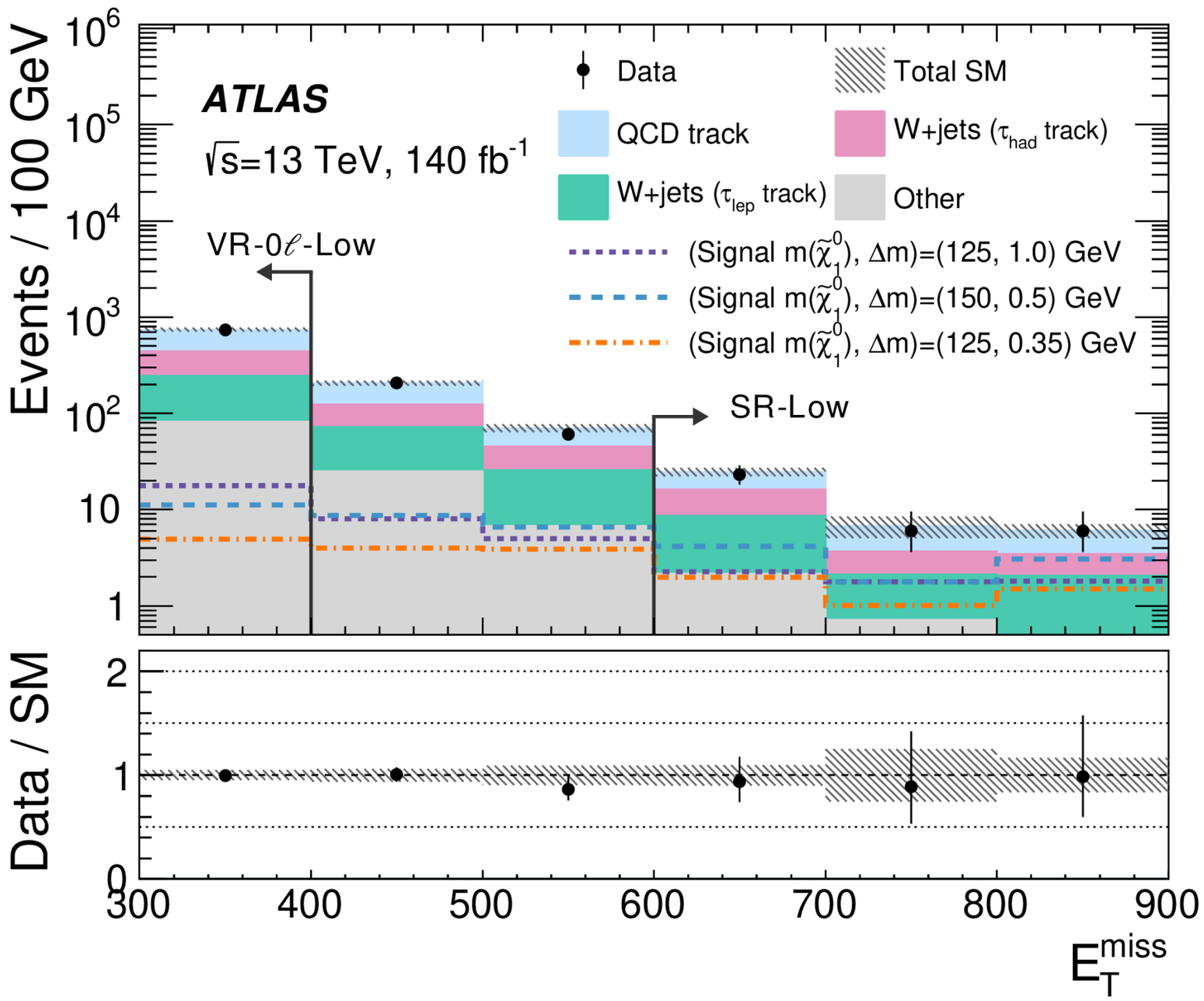
DISPLACED TRACK SR MET



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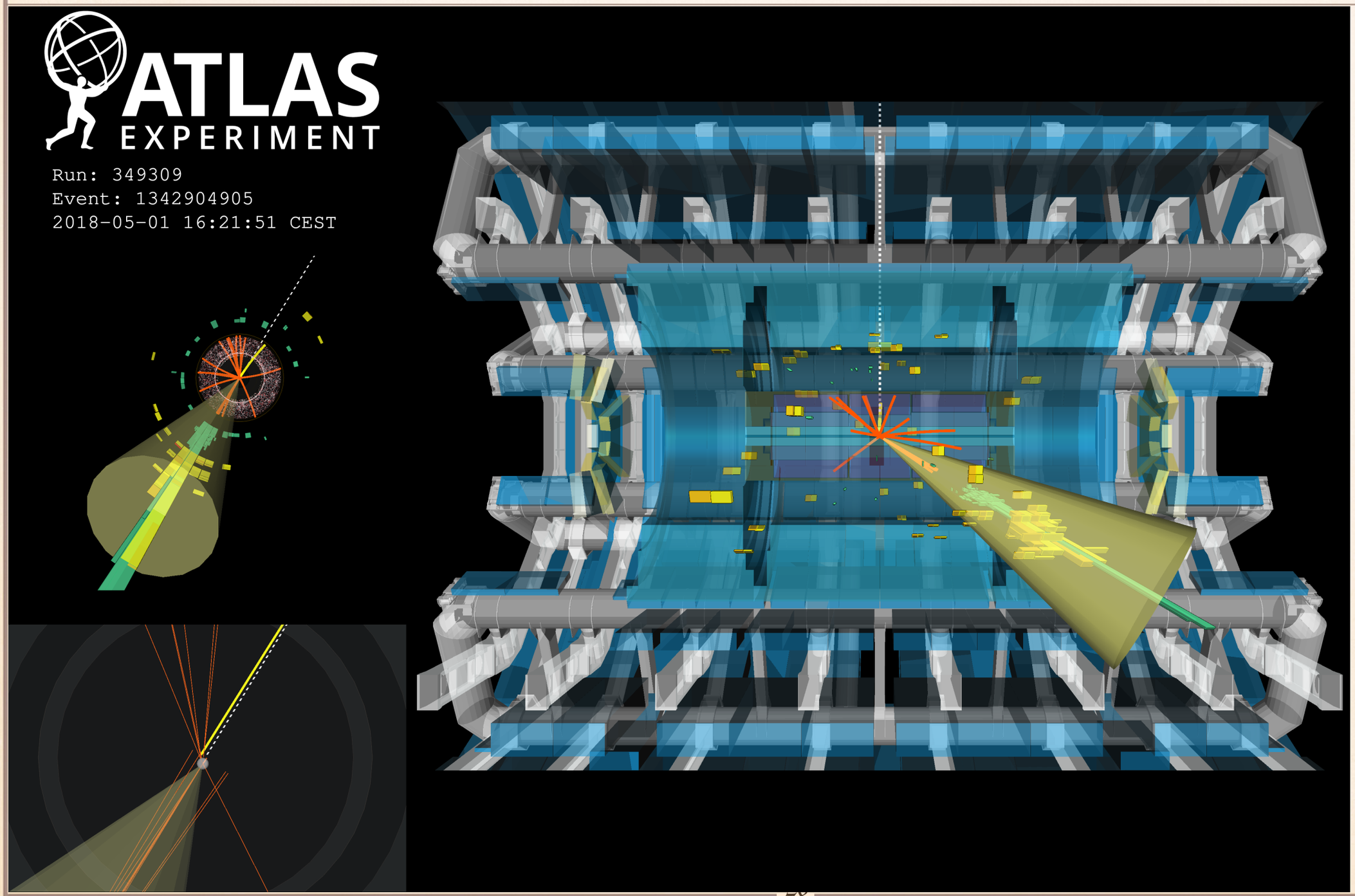
DISPLACED TRACK EVENT DISPLAY